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DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

FIRST SESSION

ON THE

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS

FEBRUARY 28, MARCH 4, 15, 21, MAY 2, AND 3, 1983

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DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

MONDAY, FEBRUARY 28, 1983

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici, Ford, and Melcher.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator **Domenici**. The subcommittee hearing will please come to order.

Good morning. This morning we will be reviewing quickly the Department of Energy's budget request for 1984 in the areas of magnetic fusion, general sciences, biological and environmental research, and supporting research in technical analysis.

In those areas the administration has requested significant increases in such programs as high energy physics, nuclear physics, basic energy sciences. This is part of an overall effort in the budget requests to highlight research and development and science and mathematics education in our schools, and I believe that the administration is to be commended for this effort.

I hope today we will be able to review these programs. I have referred to them because of their potential for benefiting the Nation in the long term, and I welcome you, Dr. Trivelpiece; if you would now proceed? You have a detailed statement. It will be made a part of the record. Proceed as you think you can best serve us with your summary or however you would like to handle it.

STATEMENT OF HON. ALVIN W. TRIVELPIECE, DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Dr. **Trivelpiece**. Thank you, Mr. Chairman. As you indicated, our fiscal year 1984 budget is approximately $1.69 billion. It does include requests for the areas that you have mentioned.

I believe that basic research is an important element in the long-term strategy to provide for the health and economic well-being of the Nation. Even in these times of budgetary stringencies the administration has made a strong commitment to support for basic research.

This commitment translates into increased budget requests for some of the programs that we are reviewing here today. These increased budget requests do not represent just a few percent more for the next good science at the margin, but rather there has been an attempt to make some selection and pick items that we believe are of particular importance to our national goals.

As a result of this selection, we have identified some initiatives. Before going into them I would like to take a brief moment to provide some background.

During the last year there have been several committees that have reviewed the national laboratories. One of these is the Energy Research Advisory Board, which of course reports to the Secretary of Energy. There have been others, one of which reports to the White House Science Council.

The theme of the recommendations of the Department's Energy Research Advisory Board [ERAB] suggests that we should look at the laboratories more as institutions and pay attention to their institutional character, rather than simply regarding them as a collection of programs which happen to be located together at one physical site. ERAB also suggested that, to some extent, we should perhaps redirect the laboratories into scientifically new or more productive areas, and that we should also try to use the laboratories in a way that better matches the needs of U.S. industry, ERAB there are many important activities that take place in laboratories which could be better matched to the needs of industry.

Finally, one of the suggestions ERAB made is that we try to utilize laboratories in a way that improves the higher education enterprise in the United States. These are certainly good suggestions, and we believe that it is important to try to use our laboratories to help the Nation remain a technological leader, but this doesn't mean that we should be using the labs as job shops for universities and industry. Rather we should try to build on and use, the laboratories unique strengths in areas where they have excelled.

The first of the initiatives that I would like to talk about involves an item that is called the National Center for Advanced Materials which we are proposing be sited at the Lawrence Berkeley Laboratory. This initiative will help redirect Berkeley into what we believe to be more productive areas of science. It will certainly build on the unique strengths that are already available at that University of California laboratory. We feel that this is important because that particular institution, Lawrence Berkeley Laboratory, is virtually colocated with the campus of the University of California and is deeply imbedded in the academic enterprise at that location and can very well accomplish the kind of goals we were talking about.

I am not going to focus on the technical features of that facility, but rather I am going to talk a little bit about what we believe might be accomplished.

As you are probably aware, there is a loss to the United States in value of about $80 billion a year due to corrosion and erosion of materials; just simply the loss of value due to those two phenomena amounts to an annual loss of $80 billion.

On the other hand, with respect to materials, the United States has certainly enjoyed an edge in competition over the years because of materials research that has taken place in the past. It is probably true that every high tech industry has some critical material at its heart, and we need to maintain the vitality in this area in order to compete in the complex high technology arena, so materials is an essential ingredient of that.

We believe that the kind of facility that will go in Berkeley will help us understand the characteristics of materials, how they are created, and furthermore, that it will also make it possible to have people trained and skilled in these arts and become available for use with industry.

Before turning to the other initiatives I want to mention, there has been expressed, and it may have come to your attention that there has been some concern by the scientific community that we have not followed the traditional role of allowing debate to take place with regard to the merits of this facility over a several year period before proposing its initiation.

While that may or may not be the case in terms of what the tradition is, we would hope for your support for these initiatives. At the same time, I am sensitive to the concerns that have been expressed, and in order to take them into account I am going to establish an ad hoc committee that reports directly to me to review the technical and programmatic features of the Berkeley advanced materials initiative. In that review, I would hope to receive good, constructive ideas from leaders from industry, other national laboratories, and from the academic community. I think it is important, however, to get on with the job, and I would like to reemphasize that I expect that the fine tuning of this particular initiative by virtue of any suggestions that may come from this ad hoc committee will not cause us to delay the initiation of this important facility.

The second initiative that I wish to talk about involves a $6 million request that we have made for university instrumentation.

As you are well aware, the university community has for several years called attention to the serious problem that the quality of instruments available for teaching and research has declined rather seriously. In effect the universities like many other segments of our society, have been eating their capital and have not kept up the facilities at the rate that they should. This erosion should be stopped as soon as possible. We believe that this initiative is a small step we can take by requesting $6 million that would go for instruments that fall in the hundred thousand to million dollar category where the need seems to be the greatest.

Other agencies are making similar requests for programs that are of interest to them. We would propose that these instruments be used for various areas of energy research of interest to DOE.

In the same spirit of upgrading facilities at universities and making appropriate facilities available for graduate education, we are proposing to have an $8 million upgrade to two nuclear physics accelerator facilities. One is located at the Yale University and the other at the University of Washington. These two institutions have been among the leaders in producing graduate students in nuclear physics research, and we believe this is an appropriate upgrading of those facilities.

The last of the initiatives I want to talk about involves a $40 million request to begin the construction of the Stanford Linear Collider at the Stanford Linear Accelerator Center. A large portion of the research, development and engineering design work necessary to bring this facility into existence has already taken place. To some extent this isn't a new initiative, because a substantial amount of work has already gone into it. We are simply proposing to begin the construction now and to complete the construction in a timely fashion. This project will markedly upgrade the existing Stanford Linear Accelerator.

This facility will permit some very important research in the area of high energy physics. That research involves the search for and investigation of the properties of new particles. You may well be aware that there is a new particle in the physics community that was discovered recently, the so-called W particle. This was discovered by the scientists at the CERN facility near Geneva. It is difficult to put, the significance of the discovery of W particle into context. Let me just briefly point out that matter is made up of protons, neutrons, and electrons and that protons are known now to be made up of still smaller objects called quarks. If you cause a proton and its antimatter version, the antiproton, to be collided at very high speeds, then every once in a while one of the quarks in the proton and an antiquark in the antiproton will collide in such a way that they annihilate. As they annihilate, they release a great deal of energy. This energy can reform into the so-called W particle which itself then decays in certain very characteristic ways.

It is by searching the debris of many thousands of the events that took place as a result of these proton/antiproton collisions at CERN that the physicists were able to find a few events in which the characteristics were unmistakable, that there had been the right decay product indicating the presence of the W particle. This was a remarkable achievement on the part of the scientists and I think they are to be greatly congratulated for this effort.

The final thing I want to mention is that since we have talked with you last year, the Tokamak fusion test reactor has come on line at Princeton. Although it is still being operated at low current levels, we are very optimistic that it will reach its full design parameters.

Mr. Chairman, that completes the introductory remarks I wish to make. I would be happy to answer any questions.

[The prepared statement of Dr. Trivelpiece follows:]

Statement of Alvin W. Trivelpiece
Director
Office of Energy Research
Department of Energy
Senate Energy and Natural Resources Committee
Subcommittee on Energy Research and Development
February 28, 1983

Mr. Chairman and Members of the Subcommittee:

I am pleased to appear before you today to discuss the FY 1984 budget request for the research programs supported by the Office of Energy Research. These programs include High Energy Physics and Nuclear Physics under the General Science and Research appropriation. Included under the Energy Supply R&D appropriation are Basic Energy Sciences, Biological and Environmental Research, Magnetic Fusion Energy, Energy Research Analyses, University Research Support, the new University Research Instrumentation program and the Multiprogram General Purpose Facilities program. It should be noted that in FY 1984, the Biological and Environmental Research (BER) program includes the Life Sciences Research and Nuclear Medicine Applications program that was formerly budgeted under the General Science appropriation. The merging of these programs recognizes the fact that there is a close interrelationship of general life sciences research to the various BER subprograms and that the BER, life sciences and nuclear medicine research efforts are managed by the same technical staff.

Let me turn now to the budget request for our programs (Table I). The total FY 1984 budget request for the programs supported by the Office of Energy Research is about $1.7 billion. Of that amount, $645.2 million falls under the General Science appropriation, with about $1.0 billion under the Energy Supply R&D appropriation. Table I summarizes the Energy Research request.

Table 1

Office of Energy Research
Summary by Program
($ in millions)

	FY 1983 Estimate	FY 1984 Request
General Sciences		
High Energy Physics	$422.2	$490.0
Nuclear Physics	130.5	153.0
General Science Program Direction	1.4	2.2
Subtotal	$554.1	$645.2
Energy Supply - R&D		
Basic Energy Sciences	$282.8	$350.2
Biological & Environmental Research	188.2	170.2
Magnetic Fusion Energy	447.1	467.0
Energy Research Analyses	2.8	2.9
University Research Support	6.0	5.5
University Research Instrumentation	0	6.0
Multiprogram General Purpose Facilities	34.0	40.6
Advisory & Oversight Program Direction	2.6	3.4
Policy and Management	1.2	0.5
Subtotal	$964.7	$1046.3
Total ER	$1518.8	$1691.5

Under General Science and Research, the FY 1984 budget request for High Energy Physics is $490.0 million. The request for Nuclear Physics is $153.0 million; and we are requesting $2.2 million for General Science Program Direction. Under Energy Supply R&D, our FY 1984 budget request includes $350.2 million for Basic Energy Sciences, $170.2 million for Biological and Environmental Research, $467.0 million for Magnetic Fusion Energy, $2.9 million for Energy Research Analyses, $5.5 million for University Research Support, $6.0 million for the new University Research Instrumentation program, and $40.6 million for Multiprogram General Purpose Facilities. Our request also included $3.4 million for Advisory and Oversight Program Direction and $0.5 million for Policy and Management.

I would like to discuss each of these programs briefly, beginning with those under the General Science and Research appropriation, and then I would be pleased to respond to questions.

HIGH ENERGY AND NUCLEAR PHYSICS

The High Energy and Nuclear Physics (HENP) programs supported by the Department fund approximately 90% of the nation's research in these fields, with the remainder supported by the National Science Foundation. These programs, which focus on experimental research using the unique facilities at DOE multiprogram laboratories, single-purpose laboratories and dedicated on-campus facilities at leading universities, have been extremely successful over the last 2-3 decades. U.S. researchers in High Energy and Nuclear Physics have won six Nobel Prizes in the last eight years and sixteen in the last 25 years. University scientists play a crucial role in these programs, conducting more than 75% of the experimental and theoretical research. The knowledge, instruments and applications that have resulted from research in these highly technological basic research areas pervade modern American society. They serve as the basis for much of our national defense strategy, for therapeutic and diagnostic medical applications, for generation of electricity with nuclear processes and for a diverse array of applications in industry and other areas of science.

The High Energy and Nuclear Physics programs are closely related in terms of goals, types of facilities and equipment used to reach those goals and the impact that research results in one program have on the other. Although the two programs do have related goals, they have quite different research emphases. Together, these programs seek a deeper understanding of the nature of matter and energy and the four basic forces of nature that interact with and cause changes in the fundamental constituents of matter. The understanding of these constituents and the physical laws governing their interactions form the basis for all of the physical sciences.

All matter that we see every day is made up of chemical elements, such as carbon, the smallest distinguishable unit of which is the atom. Within each atom there is a central core called the nucleus which contains most of the mass of the atom. The inner constituents of the atomic nucleus are protons and neutrons, which are believed to be made up of subnuclear particles called quarks. Other particles called leptons, which interact through the electromagnetic and the weak nuclear forces, also are held to be basic particles.

The Nuclear Physics program strives to attain a better understanding of the structure and properties of these atomic nuclei and the forces that govern their behavior and to determine how the quark substructure of protons and neutrons influences the make-up of nuclei (i.e., how do quarks act when they are imbedded in nuclei?). High Energy Physics research seeks to understand the nature and relationships among the four fundamental forces of nature and to understand the ultimate structure of matter in terms of the properties and interactions of its basic constituents.

Although the focus of each of the programs is somewhat different, most experiments in either the High Energy or the Nuclear Physics program depend on large particle accelerators to produce intense beams of energetic particles. These are required to probe the properties of atomic nuclei, in the case of Nuclear Physics, or to study elementary particles such as quarks and leptons and their interactions in the case of High Energy Physics. The primary experimental technique used is to study the results of collisions of high energy particles with fixed targets or with other particle beams. In these collisions, many entirely new forms of matter can be created by means of a series of energy-to-matter transformations. The study of these dynamic phenomena then reveals the properties of the underlying building blocks and basic forces involved. In general, as the particles studied become more elementary, their component parts are found to be bound together more tightly. Thus, larger, more powerful and complex accelerators, detectors and supplementary equipment are required to carry out the research.

Although progress in High Energy and Nuclear Physics is dependent on the availability of these forefront accelerator and colliding beam facilities as well as on the sophisticated detectors that record the effects of particle collisions, these advanced facilities are only one facet of the program. Progress in each of the fields of High Energy and Nuclear Physics features a continuing interplay of advancements in experiment, theory and technology. HENP experiments are done at the very forefront of theoretical and technical knowledge; and the range of experiments possible is determined by available technology. Physicists frequently have to invent unique equipment and technology to carry out the experiments of greatest importance.

In the attempt to summarize the essence of the HENP programs, it is all too easy to get lost in unfamiliar esoteric terminology. In fact, I have mentioned only a few of the hundreds of already identified or anticipated particles that inhabit the subatomic world. We have not only identified a growing number of particles, but have seen how they relate to one another and how they can be transformed during collisions with other particles in accelerator experiments. We have observed matter change into energy and vice versa; particles change into other particles which then disappear or change into still other particles. The long-standing goal of high energy physicists is to understand these diverse and complex phenomena by formulating a theory which would encompass all of the interactions of matter and energy revealed by their research. These "unified" and "grand unified" theories, as physicists call them, developed over the last 10 years, imply that the diversity existing in the universe today may have evolved from a single force, or process, that existed only when the universe was formed some 20 billion years ago.

These theories aim at linking together, or unifying, the four known fundamental forces of nature. The electromagnetic force describes how atoms and molecules are formed and is the corner-stone to understanding chemistry, electronic communications and biological processes. The weak nuclear force describes processes such as the radioactive decay of nuclei. The strong nuclear force helps describe how the nuclei of atoms can be so small and stable. The gravitational force, perhaps the most familiar of the four forces of nature, explains such things as why rocks fall and planets orbit.

Recent research results have led to an increasingly better understanding of these forces of nature. That understanding is defined in theories that indicate that the weak nuclear and the electromagnetic forces are actually different forms of a single force--referred to as the electroweak force. Two U.S. physicists shared in the 1979 Nobel Prize for work on this unification. The 1980 Nobel Prize in Physics was awarded to two U.S. physicists for work that may lead to unification of the strong nuclear and electroweak forces into what is called the grand unification theory. Eventually, it is postulated that the gravitational force will be incorporated into a super unification, thus bringing all of the basic forces into a unified framework.

In this coming year special emphasis in the High Energy Physics experimental program will be focused on testing the predictions of the currently accepted grand unified theories. Experiments will focus on further understanding the detailed properties and implications of the W particles predicted by the electroweak unified force and recently observed in Europe at CERN by a team that included U.S. physicists. CERN is the acronym for the European Organization for Nuclear Research. Experiments will also focus on effects, such as proton decay, predicted by theories that attempt to unify the strong and electroweak forces. If experiments currently underway confirm the validity of these theories, there would be a major scientific breakthrough in understanding the basic forces of nature. These new concepts may, in time, lead to an understanding of how the universe evolved from the hypothesized "big bang" to its present state and such interesting questions as whether the universe will continue to expand.

The history of progress in High Energy and Nuclear Physics research allows us to say confidently that we are moving steadily toward our long-term goal of understanding the physical world around us. But we get even more from this research. There have been many spin-offs, including the technology of superconducting materials and devices, radio frequency power generation, materials analysis and medical applications, including methods of treating cancer.

More recently, the use of synchrotron light from particle accelerators opened up totally new research capabilities in chemistry, solid state physics, biology and industrial applications. Free-electron lasers, driven by particle accelerators, promise new capabilities for enhanced laser power and control. Radiation processing of materials, which was born from this science, has many exciting new applications ranging from the manufacture of heat-shrinkable electrical insulation to the sterilization of wastes. Although we cannot predict them in advance, history has shown that these kinds of technological advancements are virtually guaranteed tangible benefits that we expect to continue to reap as a result of our investment in basic research, including High Energy and Nuclear Physics research.

HIGH ENERGY PHYSICS

Let me turn now to the FY 1984 budget request for High Energy Physics. The FY 1984 budget request of $490.0 million for High Energy Physics compares to the FY 1983 estimate of $422.2 million (Table 2). This increase of $67.8 million would permit a High Energy Physics program with an estimated utilization rate of 55% for the existing accelerators, solid support for university based experimental user groups and theoretical research efforts, continued progress on the Fermilab facility development program, and the initiation of construction on a rapid schedule of the high priority Stanford Linear Collider (SLC) project at the Stanford Linear Accelerator Center (SLAC). The Operating Expenses request for FY 1984 is $349.5 million; the Capital Equipment request is $51.5 million; and the Construction request is $89.0 million.

The high energy particle accelerator and colliding beam facilities that would be operated under the requested FY 1984 budget include the 30 billion electron volt (GeV) proton Alternating Gradient Synchrotron at Brookhaven National Laboratory (BNL), the 500-1000 GeV proton synchrotron at the Fermi National Accelerator Laboratory (Fermilab) and the 32 GeV linear electron accelerator at SLAC. SLAC also has two electron-positron colliding beam facilities for which the linear accelerator acts as the injector. These facilities are called SPEAR and the Positron-Electron Project (PEP). Each of the three national accelerator centers (Fermi, SLAC, BNL) provides a unique set of capabilities that complement the others. Together, they represent the experimental facilities essential for a comprehensive national research

Table 2

High Energy Physics
Budget Authority
($ in Millions)

	FY 1983 Estimate	FY 1984 Request
Operating Expenses		
Physics Research	$ 92.2	$ 101.5
Facility Operations	152.1	166.0
High Energy Technology	76.0	82.0
	320.3	349.5
Capital Equipment	46.4	51.5
Construction	55.5	89.0
Total High Energy Physics	$ 422.2	$ 490.0

program in High Energy Physics. The major part of the High Energy Physics funding is required to meet the direct needs of these accelerator laboratories. While these three accelerators provide the experimental data sources for almost all accelerator-based High Energy Physics research in the U.S., about 75% of that research is carried out by teams of researchers from the Nation's colleges and universities. Thus, about three-quarters of the funding provided to the accelerator laboratories can be considered as indirect support of the university program.

The FY 1984 budget request for Operating Expenses of $349.5 million would provide for the first full year of operation of the Energy Saver superconducting synchrotron at Fermilab. The Energy Saver, the first stage of a multi-step development program, will reduce electric power needs and extend operation of the accelerator to 500 GeV for fixed-target experiments. With completion of early phases of the Tevatron II project, the third stage of the development program, operation at energies approaching 1000 GeV should be possible. Priority also would be given to good operation and research use of PEP, the 15 GeV x 15 GeV electron-positron colliding beam facility at SLAC. The FY 1984 Operating Expenses request would provide strong continuing support for university research groups, non-accelerator experiments and theoretical research efforts.

This FY 1984 request also includes funding for Brookhaven National Laboratory (BNL) to continue to develop accelerator-quality superconducting magnets, to develop and demonstrate techniques for fabricating the magnets reliably, and to consider lower cost magnet options. Funding is also provided to develop alternative facility designs that would use the tunnel now in existence at BNL. We anticipate a proposal from BNL at the end of March describing their new facility plans, cost and schedule estimates. DOE plans an in-depth review of the BNL proposal in April; a study of High Energy Physics facility needs will be carried out by a Subpanel of the High Energy Physics Advisory Panel (HEPAP) in June and HEPAP will review their report in July. DOE expects to make a decision in July on whether to initiate construction of a new colliding beam facility at BNL in FY 1985.

The Capital Equipment request of $51.5 million gives priority to Fermilab for equipment related to the major detector for colliding beam experiments at Tevatron I and for secondary beam line components and detectors for 1000 GeV experiments at Tevatron II, and to SLAC for work on a detector for SLC research. To accommodate these needs, other programs remain at a somewhat reduced or near constant level of effort.

The FY 1984 Construction request is for $89.0 million, an increase of $33.5 million over FY 1983 (Table 3). A major portion of this request is to initiate construction on the SLAC Linear Collider (SLC) on a rapid schedule. The goal of this project is to develop and demonstrate the practicality of using linear accelerators with precisely controlled, high intensity and highly focused beam pulses to provide high luminosity electron-positron or electron-electron collisions at energies far beyond those that will be affordable for circular colliders. Luminosity is a measure of the rate at which events can be recorded for a given process.

Table 3

High Energy Physics
Budget Authority
($ in Millions)

Construction	Prior Years	FY 1984 Request	TEC	Completion Date
Tevatron I (81-E-218)	$ 34.1	$ 20.0	$ 82.5	FY 1986
Tevatron II (82-E-206)	24.8[a]	13.0	49.0	FY 1985
Stanford Linear Collider (84-ER-133)	2.0[b]	40.0	112.0	FY 1986
Accelerator Improvement Projects (84-ER-131)	N/A	9.0	9.0	FY 1985
General Plant Projects (84-ER-132)	N/A	7.0	7.0	FY 1986
Total Construction		$ 89.0		

a/ Includes $800,000 for PE&D
b/ Represents $1,957,000 for PE&D

Completion of the SLC on a three year construction schedule will give the U.S. earliest access to copious production of a previously unidentified particle called the Z^0 (pronounced zee-zero) which is a critical prediction of the electroweak force theory. Also included in the Construction request is the continuation of the Tevatron I and II projects at Fermilab. These projects comprise the second and third stages of the multi-step development program. Tevatron I permits acceleration up to 1000 GeV and will provide a facility for proton-antiproton collisions at 1000 GeV. Tevatron II will further expand the accelerator's capabilities by providing upgrading of experimental areas and beam lines external to the main ring for fixed target experiments. The remainder of the construction request is for Accelerator Improvement Projects essential to maintain the reliability, efficiency and scientific effectiveness of the existing accelerator facilities and for General Plant Projects essential to the efficient and reliable operation of the laboratory sites.

NUCLEAR PHYSICS

The FY 1984 budget request for Nuclear Physics is $153.0 million, an increase of $22.5 million over the FY 1983 estimate (Table 4). Of the $153.0 million request, $128.0 million is for Operating Expenses, $11.3 million is for Capital Equipment and $13.7 million is for Construction. This budget request provides for experimental and theoretical studies aimed at improving our fundamental understanding of atomic nuclei.

Table 4

Nuclear Physics
Budget Authority
($ in Millions)

	FY 1983 Estimate	FY 1984 Request
Operating Expenses		
Medium Energy Nuclear Physics	$ 52.3	$ 59.0
Heavy Ion Nuclear Physics	39.7	47.0
Low Energy Nuclear Physics	12.2	13.0
Nuclear Theory	8.2	9.0
	112.4	128.0
Capital Equipment	10.4	11.3
Construction	7.7	13.7
Total Nuclear Physics	$ 130.5	$ 153.0

Because nuclear interactions and the behavior of nuclei and nuclear matter determine the physical properties of our universe, quantitative knowledge of nuclei is essential to any basic understanding of the world about us. The Nuclear Physics program is an important element in America's long term investment in its technological future with nuclear processes. As an ancillary benefit, pursuit of Nuclear Physics program goals provides a national base of knowledge, techniques, instrumentation, and skilled manpower in critical technologies.

In addition to talented scientists, the success of the Nuclear Physics program depends upon the existence and effective operation of large and complex accelerator facilities. These facilities are the essential tools of the nuclear scientist. They provide the variety of particle beams which are required for forefront nuclear research. In FY 1984, our highest priority will be to maintain the capability of these facilities to meet evolving research requirements and to operate these facilities a sufficient number of hours in FY 1984 to meet the needs of the research program.

In FY 1984, emphasis in the Nuclear Physics program will be given to exploitation of new research capabilities provided by successful completion of construction projects in FY 1982 and FY 1983. These capabilities include: (1) the ability to accelerate ions as heavy as uranium to low energies in the SuperHILAC and to high energies in the Bevalac (Lawrence Berkeley Laboratory); (2) the completion of the Bates Electron Accelerator recirculator project at the Massachusetts Institute of Technology (MIT) that provides electron beams for precision electron-nuclear scattering studies at higher energies than previously available; and (3) newly available heavy ion beams at the Holifield Heavy Ion Research Facility (Oak Ridge National Laboratory) and the Argonne Tandem/Linac (Argonne National Laboratory) that will allow high precision heavy ion physics studies at higher energies than previously available.

The underlying quark structure of protons and neutrons must play an important role in the makeup of nuclei. However, understanding and quantifying this role remains an important task before us. High priority experiments in FY 1984 are planned with LAMPF's (Clinton P. Anderson Meson Physics Facility at Los Alamos National Laboratory) intense pi meson beams and with Bevalac's new high energy uranium beam capability. Another important thrust in this quark substructure effort is high energy electron scattering experiments at the Stanford Linear Accelerator Center (SLAC). The FY 1984 Nuclear Physics Accelerator Improvement and Modification construction project request includes $1.65 million for a new injector at SLAC for these experiments as well as for research to understand the magnetic structure of nuclei.

Experiments which examine the weak interaction and properties of the neutrino will also be a major thrust of the FY 1984 Nuclear Physics program. The weak interaction governs beta decay of nuclei and is one of the three fundamental forces which determine the characteristics of nuclei. In FY 1984, highlights of this area of emphasis include research with polarized electron beams at Bates and with LAMPF's uniquely pure and intense muon and neutrino beams.

In FY 1984, emphasis will be given to heavy ion research with ions more massive than calcium and in the projectile energy range above 10 MeV (million electron volts) per nucleon. In particular, the newly available beams at the Holifield, the Bevalac low energy beam line, and the Argonne Tandem/Linac will be used to study the mechanisms by which colliding nuclei exchange mass, energy, and angular momentum. Above 30 MeV per nucleon, the projectiles are moving at velocities comparable with and exceeding the average internal velocity of neutrons and protons inside the individual nuclei. Collisions of target nuclei with projectile nuclei at these energies cause formation of intense concentrations of energy and mass. From these experiments, we expect to learn how nuclear matter acts as it is compressed and how energy moves through nuclear matter.

Of the $128.0 million Operating Expenses request for FY 1984, $66.3 million is needed for operation of Nuclear Physics accelerator facilities, with twelve million of this for electric power costs. This funding will allow use of facilities at the same levels as achieved in FY 1982. The remainder of the Operating Expenses request is for experimental research ($52.7 million) and theoretical research ($9.0 million).

In FY 1984, $11.3 million is requested for Capital Equipment. Of that, $10.5 million is needed to acquire experimental and computational equipment used by research scientists as well as equipment which permits effective operation of the accelerators themselves. The most important type of capital equipment needed is the detection system. New and more sophisticated detectors and analytical systems are needed to isolate the particular nuclear events that can provide new information about nuclear phenomena. The remaining $0.8 million is needed to meet Lawrence Berkeley Laboratory's laboratory-wide requirement for general purpose equipment.

The FY 1984 request for Construction funds for Nuclear Physics is $13.7 million (Table 5). The Accelerator Improvement Projects request includes $1.65 million for the new SLAC injector which I discussed earlier. This injector would produce electron beams with an intensity 100 times greater than the currents now available. The injector will permit experiments that will improve our understanding of electromagnetic properties of nuclei and of the quark structure of nuclei.

Because accelerator facilities have continuous needs during their operating lives for small modifications or additions that improve their performance and enhance their usefulnesses, the FY 1984 construction request also includes Accelerator Improvement Projects and General Plant Projects funds for such activities at the Bevalac, the Clinton P. Anderson Meson Physics Facility, and the William H. Bates Electron Linear Accelerator. The General Plant Projects request also includes funds for the laboratory-wide needs of Lawrence Berkeley Laboratory.

Work by university-based nuclear scientists is a prominent component of the Nuclear Physics program. University scientists conduct experiments at the national accelerator facilities and at dedicated on-campus accelerator

Table 5

Nuclear Physics
Budget Authority
($ in Millions)

Construction	FY 1984 Request	TEC	Completion Date
Univ. Accelerator Upgrade (84-ER-110)	$ 8.0	$ 19.0	FY 1987
Accelerator Improvement Projects (84-ER-121)	3.5	3.5	FY 1986
General Plant Projects (84-ER-122)	2.2	2.2	FY 1986
Total Construction	$ 13.7		

facilities. To maintain the scientific strength and attractiveness of university-based nuclear physics facilities to students, these facilities must be maintained at scientifically competitive levels. In the FY 1984 request for Construction funds, $8.0 million is planned for upgrade of on-campus accelerator facilities at Yale University (New Haven, Connecticut) and the University of Washington (Seattle, Washington). The upgraded facilities will allow continuation of the excellent records of scientific productivity and academic preeminence of these outstanding institutions.

GENERAL SCIENCE PROGRAM DIRECTION

The FY 1984 budget request for General Science Program Direction is $2.2 million. These funds are required to provide for the salaries, benefits, travel and other expenses associated with 35 full-time equivalents in the Office of the Associate Director for High Energy and Nuclear Physics and associated support staff required to administer these programs.

I would now like to discuss the programs under the Energy Supply R&D appropriation, beginning with Basic Energy Sciences.

BASIC ENERGY SCIENCES

Although the U.S. is in much better shape today than it was 10 years ago with regard to our reliance upon foreign energy sources, there is a continuing need to expand our energy supply and conservation technology base. This is the primary role of the Basic Energy Sciences program. While the current energy situation has reduced the Department's primary focus on short-term problems, the Basic Energy Sciences role - aimed at the longer term - continues to be very important to the future of the nation. Furthermore, while the pursuit of research by Basic Energy Sciences to broaden the technology base for identified technologies continues to be important, even more important is the need for basic scientific research unconstrained by preconceived notions of which technologies will be important in the future. The Basic Energy Sciences program supports approximately 1200 research projects and provides advanced facilities that are used by university and industrial researchers as well as national laboratory scientists. Research is carried out in material sciences; chemical sciences; nuclear sciences; engineering, mathematical and geosciences; and biological energy research. An advanced energy projects effort that crosscuts all disciplines is also included.

It is difficult to convey the impact of the BES program by citing yearly research accomplishments. Scientific findings form a base of knowledge from which improvements to existing technologies or new ones evolve. Often it is only in retrospect that the true importance of research results can be assessed. However, the following examples of research results in FY 1982-1983 that have enhanced energy alternatives or improved our understanding of energy-related phenomena are illustrative of the benefits to be gained from research in the basic energy sciences.

Research in Materials Sciences has resulted in new information that:

- should improve our understanding of the useful properties of superconductivity, which may lead to advancements such as improved superconducting electrical cables important in several advanced technologies;
- will provide a better understanding of the control of stress corrosion cracking of nickel base alloys, a well-known cause of costly unscheduled outages in nuclear power plants; and
- explains the radiation swelling mechanism of a ceramic material potentially useful as a long-term storage host for nuclear waste.

Research in the Chemical Sciences subprogram has led to:

- An improved ability to measure the ratio of sulfur-32 isotope to sulfur-34 in the air. This new capability is based on negative ion mass spectrometry which allows much more sensitive measurements than the traditional positive ion mass spectrometry. This improvement is critical to establishing a reliable measurement technique that could be used to distinguish among the different kinds of sources of sulfur present in the air. Conceivably the discovery could be used in future efforts to reduce the environmental effects of coal combustion.

- Observance of a phenomenon, called "hot carrier effects", that had been theoretically predicted for semiconductor/liquid interfaces. Hot carriers are electrons or positive charges carrying excess energy that are produced by light in semiconductors. If it can be harnessed, this phenomenon could lead to a doubling in the efficiency of photoelectrochemical solar devices.

Several accomplishments under the Nuclear Sciences program relate to nuclear energy. These include:

- The fluorescence emitted from electronically excited plutonium hexafluoride (PuF_6) due to laser exposure of vapor molecules of the PuF_6 was detected for the first time. Large differences were found between PuF_6 and uranium hexafluoride. These differences will mean that process conditions (e.g., laser wavelengths, temperatures) will have to be different for separating plutonium isotopes and uranium isotopes.
- It was also found in studies of the binding of actinides to naturally occuring organic materials that migration of plutonium through soils rich in these materials would be very slow.

Work under the Engineering, Mathematical and Geosciences subprogram included:

- An applied math effort involving automated reasoning that provided a solution to the problem of showing that single component failures could not inhibit the shutdown of a nuclear reactor. This type of verification is a useful tool in nuclear plant licensing procedures.
- A geosciences effort that showed that Columbia River basalts have chemical properties that can provide a safety factor by the immobilizing long-lived actinides such as neptunium.

A recent accomplishment under the Advanced Energy Projects subprogram has been demonstration of the scientific feasibility of producing storage and primary batteries with electrodes made of light polyacetylene sheets rather than lead. The successful demonstration of this concept could pave the way for a whole new technology and considerably improve the outlook for electrically-powered vehicles.

The Biological Energy Research subprogram has made progress in determining how plant systems sense temperature. It has been found that plants adapt to the environment. Control of plants' adaptive responses could lead ultimately to artifically adapting plants to specific environments, for example, for producing biomass in geographic areas where it is not now economically feasible.

At the heart of the Basic Energy Sciences program is the need for program continuity concurrent with reasonable opportunities for growth in newer, emerging areas of science. To continue its effectiveness, the BES program must: 1) maintain a strong core program -- this involves equipping, supporting and encouraging the scientists involved in our current program activities, 2) have growth opportunity to exploit new, emerging areas with great potential importance to energy and 3) continue to support existing, unique facilities while at the same time providing for needed new facilities and their operation.

Research facilities are an integral part of the overall BES program and I would like to briefly explain the progress we are making in this area. BES has recently completed construction of three important user facilities: the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory; the Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory; and the 1.5 MeV Atomic Resolution Microscope (ARM) at Lawrence Berkeley Laboratory (LBL). FY 1983 will be the first full year of operation of these new facilities. The NSLS will provide intense beams of photons in the ultraviolet and x-ray regime to enable studies of surface properties and structures not possible before. The microscope will permit examination of materials while in a corrosive environment and the IPNS can be used to investigate the fundamental vibrational modes of atoms in solids. In FY 1983 the ARM at Lawrence Berkeley Laboratory will begin operation and the National Science Foundation transfers to BES the responsibility for the operation of the Stanford Synchrotron Radiation Laboratory (SSRL), our second major research facility for synchrotron radiation. In addition, FY 1982 was the first full year of operation of the Combustion Research Facility (CRF) at Sandia National Laboratory, Livermore. This facility provides advanced and unique laser diagnostic tools to a user community consisting of scientists and engineers from academia, industry and government laboratories, all studying fundamental aspects of combustion. Among the areas investigated during the past year were aspects of soot formation, and nitrogen oxide reduction in engine exhausts. Much remains unknown in the complex and very rapid phenomena of combustion, and the advent of the CRF puts the U.S. in the scientific lead in this field.

Having briefly discussed the goals and accomplishments for the BES program, I would now like to turn my attention to the program and budget that we are requesting in FY 1984 (Tables 6 & 7). The total request for FY 1984 is $350.2 million and is composed of $295.8 million for Operating Expenses, $24.3 million for Capital Equipment and $30.1 million for Construction. The increase requested is $67.4 million above the FY 1983 level of $282.8 million and I would like to explain this increase. First, as I have mentioned earlier, we must continue to support a strong core research program including the National laboratories, universities, and industrial communities. Secondly, we must expand and fully utilize equipment and facilities to, at a minimum, keep pace with international competition and

Table 6

BASIC ENERGY SCIENCES
Budget Authority
($ in millions)

	FY 1983 Estimate	FY 1984 Request
Operating Expenses		
Nuclear Science	$ 30.6	$ 37.9
Material Science	108.7	125.1
Chemical Science	70.0	75.5
Engineering, Mathematical and Geosciences	31.1	33.7
Advanced Energy Projects	8.3	9.1
Biological Energy Research	9.5	10.6
Program Direction	3.1	3.9
	261.3	295.8
Capital Equipment	18.1	24.3
Construction	3.4	30.1
Total Basic Energy Sciences	$ 282.8	$ 350.2

Table 7

BASIC ENERGY SCIENCES
Budget Authority
($ in millions)

	Prior Years	FY 1984 Request	TEC	Completion Date
NSLS Beam Lines and Support Area Construction, BNL	0	$ 2.5	$19.7	FY 1986
National Center for Advanced Materials, LBL	0	25.9	138.9	FY 1989
Accelerator Improvement Projects	N/A	1.3	1.3	FY 1985
General Plant Projects	N/A	0.4	0.4	FY 1985
Total		$30.1		

our own needs. Finally, we must exploit new research opportunities that appear to hold promise of significant breakthroughs important to energy. The budget that we are requesting for FY 1984 will accomplish these goals.

The principal components of the increases sought above for FY 1983 are:

- o First, the FY 1984 budget request provides for a cost of living allowance of $15.4 million and allows a modest $8.9 million growth in the various subprograms in the most promising new research areas. Included are the funds needed to meet increased costs for facility operations, and for equipment replacements and additions, as well as for program direction.
- o Second, the FY 1984 budget provides for an Advanced Materials Research initiative of $38.0 million which includes two major construction projects and directly related research and equipment. The new construction projects are the National Center for Advanced Materials at LBL and an expansion of capability at the National Synchrotron Light Source at Brookhaven National Laboratory.

In addition, the FY 1984 budget request includes an increment of $5.0 million for Heavy Ion Fusion Research, a program transferred to Basic Energy Sciences from the Office of Inertial Fusion, Defense Programs.

The first item which I mentioned is fairly straightforward but I would like to spend some time discussing the materials initiative and the transfer to BES of the Heavy Ion Fusion program. The Advanced Materials Research initiative builds on the base of knowledge established by the Materials Sciences program. It will complement ongoing core program activities. It will also help maintain U.S. leadership in the field of materials sciences. Research in materials sciences contributes to developing new or substitute materials, tailoring materials for specific applications, predicting materials problems and service life, and improving our ability to deal with unforeseen materials problems in advanced energy systems. Additional research is required to answer a myriad of materials-related questions and is recommended in a series of studies performed by leaders in the scientific community. This initiative takes a substantial step in meeting the existing and projected needs for new work in surface science and catalysis, materials preparation and characterization, and the concepts behind materials as they are used in devices, both large and small.

Of the $38.0 million request for the materials initiative, $7.7 million is for Operating Expenses, $1.9 million is for Capital Equipment and $28.4 million is for Construction. Included in the Construction request would be a National Center for Advanced Materials (NCAM) composed of four new facilities and improvements at the SSRL ($25.9 million). The total TEC is $138.9 million of which we are requesting $28.4 million in FY 1984. The new facilities would include an Advanced Light Source and Surface Science and Catalysis Laboratory, an Advanced Materials Synthesis Laboratory and an Advanced Device Concepts Laboratory. Also included in the materials initiative is an expanded capability at the National Synchrotron Light Source ($2.5 million).

The Advanced Materials Research initiative will be organized to include participation by U.S. industry as well as universities and laboratories. Industry will participate in the design and use of the facilities to assure that the research addresses appropriate high-technology needs. For example, at the National Center for Advanced Materials (NCAM), an advisory board composed of scientific leaders from industry, universities, and laboratories will advise the LBL director on NCAM scientific program directions. The NSLS and SSRL already have active industrial participants and advisory groups that effectively interact with the scientific community at large. These new facilities and the involvement of industry will provide otherwise unavailable research capabilities that will improve on the U.S. competitive position in high-technology over the long term.

In FY 1984, the Heavy Ion Fusion Research program will be transferred from the Office of Inertial Fusion, Defense Programs to the Office of Energy Research. Within ER, it will be located under the BES Nuclear Sciences subprogram. The program has been moved in response to Congressional guidance contained in Conference Report 97-342 on the Authorization Act for DOE national security programs for 1982. The guidance stated that heavy ion fusion research which is directed toward development of new energy sources should not be funded from the defense inertial confinement program. The goal of the Heavy Ion Research program is to develop heavy ion accelerator technology and perform appropriate ion beam experiments to develop an adequate data base for evaluation of heavy ion inertial fusion drivers and their possible use in civilian power applications of inertial confinement fusion.

I will now describe the Biological and Environmental Research program.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH

The effects of new and existing sources of energy on human health and the environment are concerns shared by the whole country. The Biological and Environmental Research (BER) program is the only long-term, multidisciplinary research effort in the Federal Government specifically devoted to the range of environmental and health issues that we are likely to face in expanding existing energy technologies, or developing new energy sources. The goals of this research are to identify, before a technology is locked into place, the early and late effects, if any, on human health and the environment. Answers to these questions, if obtained early enough, will permit energy requirements to be met with minimum damage to human health and the environment. In addition, these answers will prevent the expenses associated with unnecessarily restrictive regulations and delays in deploying the technology.

This research program began 35 years ago to look at ways of measuring radiation, understanding the major processes that move radionuclides back through the environment to man, and how radiation affects human health. Now, a number of years later, it is apparent that many of the same biological questions that have been studied in radiation-related research must also be answered with respect to the effects of energy-related chemicals on human health (e.g., what is the impact on mutation rates and cancer incidence, on reproductive functions and on critical organ systems like the lungs and bone marrow). The same processes in the environment, the same interactions at the cellular level, and the same types of damage to DNA and other cell components are characteristic of other energy-related pollutants as well.

In addition to improving our understanding of the effects of radiation on man and the environment, one of the major accomplishments of this research program is the reduction in human pain and suffering that results from advances made in the Nuclear Medicine program. These advances have greatly reduced the need for exploratory surgery. Using isotopes and advanced imaging equipment developed by our contractors, doctors can treat diseases and examine a beating heart or a functioning brain to detect problems, if they exist, before they become life threatening. The ideas and inventions developed in this program have been transferred to and commercialized by industry and are used in hospitals throughout the world.

Much progress has been made in understanding the health and environmental issues associated with energy technology developments, but more research is needed. Since most of the questions which need to be addressed are generic in nature, the BER program will focus on the long-term, basic and applied research needed to resolve these issues. The FY 1984 budget request for Biological and Environmental Research is $170.2 million, a decrease of $18.0 million. Of this amount, $161.5 million is for Operating Expenses, $7.7 million is for Capital Equipment, and $1.0 million is for construction (Table 8).

In FY 1984 the BER program includes the Life Sciences Research and Nuclear Medicine Applications programs formerly budgeted under the General Science and Research Appropriation. The merging of these programs recognizes the fact that there is a close interrelationship of general life sciences research with

Table 8

Biological and Environmental Research
(B/A in millions)

	FY 1983	FY 1984
Operating Expenses	$174.2	$161.5
Capital Equipment	12.0	7.7
Construction	2.0	1.0
Total	$188.2	$170.2

the various subprograms of BER and that both programs, as well as the Nuclear Medicine Applications research effort, are managed by the same technical staff.

The level of funding requested in this budget will allow us to continue to obtain new data needed by the Department and the Nation to allow us to make program and policy decisions that will ensure effective and environmentally acceptable use of the present and future energy options and safe conduct of national security activities. To obtain the data needed to address health and environmental issues, a multidisciplinary research effort is needed. Therefore, the Biological and Environmental Research program is organized and managed by discipline. These disciplines, or subprograms, include Human Health Research, Health Effects Research, Environmental Research, Physical and Technological Research and Nuclear Medicine Applications. Funding by various subprograms is shown in Table 9. I would like to take a moment now to summarize the FY 1984 budget request in each of these areas.

Human Health Research

The principal objective of the Human Health Research subprogram, for which $24.4 million is requested in FY 1984, is to determine whether exposure of humans to agents associated with atomic energy defense activities and energy production and use results in such health effects as cancer and genetic defects. Since these diseases do not manifest themselves until years after exposure, long-term epidemiological studies of relatively large numbers of exposed and control individuals must be followed to determine whether correlations between radiation exposure and disease incidences actually exist. Nearly

Table 9

Biological and Environmental Research
(B/A in millions)

	FY 1983	FY 1984
Human Health Research	$ 25.8	$ 24.4
Health Effects Research in Biological Systems	58.5	51.9
Environmental Research	25.6	22.6
Physical & Technological Research	29.3	26.0
Health & Environmental Risk Analysis	1.7	0
Nuclear Medicine Applications	21.0	21.0
Program Direction	3.3	3.6
Subtotal Operating Expenses	$165.2	$149.5
Capital Equipment	12.0	7.7
Construction	2.0	1.0
Total BER/OHER	$179.2	$158.2
Carbon Dioxide Research	9.0	12.0
Total Biological and Environmental Research	$188.2	$170.2

two-thirds of this subprogram budget is "mortgaged" for studies of over one million individuals who have been exposed to radiation. In these investigations we are studying the Japanese A-bomb survivors, and U.S. workers from nuclear shipyards, uranium mines, reactor operations and the now defunct radium watch dial industry. These studies continue to yield important data on the radiation-induced effects in humans who have been exposed to both external radiation and internally deposited radionuclides. The FY 1984 budget request would provide for improvements in the precision of our studies of nuclear workers, and would continue the current program at a level that will ensure that useful results are obtained in a timely manner.

Although the major emphasis of the program has been on health effects from radiation exposure, in recent years the human health research program has been expanded modestly to include selected, small scale research efforts on populations of individuals who have been exposed to chemicals from nonnuclear energy technology sources and conservation options. This nonnuclear research will continue at a reduced level.

Health Effects Research

Ideally, human health risks should be estimated from data obtained in studies of human responses to toxic agents. However, it is not possible to experiment with humans, and existing human data are rarely adequate for making reliable health-risk estimates. Therefore, epidemiological data must be supplemented with information from studies of animals and other living systems. Research in the Health Effects Research subprogram, for which $51.9 million is requested in FY 1984, is providing data which can be used to quantify dose-response relationships in experimental animal systems. In addition, experimental animals, as well as molecular and cellular systems, are being used to study how physical and chemical toxicants induce health effects and to evaluate the many variables (e.g., level, rate and route of exposure) that may affect how humans respond to harmful environmental agents.

Information obtained in these experimental systems permits one to establish the fundamental concepts and scientific data base needed to confirm or improve predictions of health impacts in exposed human populations. Emphasis in the program, which often requires unique experimental facilities, is placed on determining the delayed biological effects that are induced by repeated or chronic exposures to low concentrations of toxic agents. Three categories of health effects are investigated: cancer, genetic damage, and toxicity to functional systems of the body.

In the radiation area, research continues to develop quantitative information on the cancer risks associated with exposures to low-doses of radiation from external radiation sources and from radionuclides deposited in body tissues. Of major importance are a series of ongoing lifetime studies with dogs exposed to plutonium, other transuranic elements and long-lived fission products by inhalation, ingestion, or injection.

Since there is no data base available on the biological effects produced in humans following exposure to neutrons, research also is being conducted at several DOE laboratories to investigate mechanisms of neutron-induced cancer in experimental animals and in mammalian cell systems. Recent data obtained at the Argonne National Laboratory JANUS reactor have demonstrated that long-term repetitive low doses of neutrons produce more tumors and more cell transformations than occur when the equivalent total neutron dose is delivered over a shorter period of time. Because of the importance of these data for estimates of risk to workers at nuclear facilities, including power and weapon fabrication plants, emphasis in FY 1984 will be directed to obtaining more quantitative information as well as data on the mechanisms involved in this enhanced neutron effect.

Our research also addresses health issues related to the production and use of America's vast fossil reserves. The products, byproducts, emissions and process streams of synthetic fuel processes contain thousands of chemical compounds whose health effects are unknown. Because of the complexity of these mixtures, new methods were needed to identify those compounds that might adversely affect living organisms, and to study the nature of these effects. Accordingly, reliable short-term tests, including the well known Ames test, were developed to identify those chemicals capable of causing genetic damage or cancer.

As a result of recent short-term research, we now have a much better understanding of the potentially hazardous chemical compounds involved in synfuel processes. In summary, we now know that relatively few compounds out of the thousands present in complex synfuel materials are biologically toxic and that these same components appear to be responsible for the toxicity of synfuel materials regardless of the process used to produce the fuel. On the basis of this knowledge, we can now focus our longer-term research efforts on fewer, more generic questions. It is our intent to conduct research on (1) the genetic and late biological effects produced by representative energy-related chemicals about which little or nothing is known, (2) the fundamental mechanisms involved in initiation, promotion and inhibition of cancer expression, and (3) the biological effects produced by these complex mixtures of chemicals, since most individuals will be exposed to complex mixtures, rather than individual compounds.

Basic molecular and cellular research also will continue to use powerful new biophysical and genetic research tools as probes to improve insights into the structure, properties, and functions of cell proteins, nucleic acids, and other cell constituents that are targets of both physical and chemical pollutant action.

Environmental Research

The FY 1984 budget request for the Environmental Research subprogram is $22.6 million. This request would continue to support the Department's basic environmental research program. Through Environmental Research we are learning about the mechanisms that control and influence total ecosystems and the critical elements within them so that we can conduct defense activities and site and operate energy systems in a cost-effective, environmentally safe manner.

To obtain this information base, an interdisciplinary research program in terrestrial and aquatic systems is conducted in different climatic regions and in offshore regions along the east and west coasts of the U.S. This research is designed to: (1) identify how energy and weapons-related materials are transported through and changed in the environment; (2) determine effects of defense and energy activities on critical ecosystems and the resiliency of these systems to continued stress; (3) manipulate damaged ecosystems to determine the most beneficial methods of recovery; and (4) identify processes used by plants and animals in degrading and detoxifying pollutants in the environment.

To accomplish these tasks, the program investigates the cycling of natural, defense and energy-related materials through land and marine environments as well as the way that biological systems respond to stress. In cycling research, inorganic and organic compounds and radionuclides are identified as they move and change form through water bodies, soils, and sediments. Availability of these materials to plants and animals is determined, including studies on plant uptake through roots and leaves, thus incorporating the materials into the food chain. Studies on cycling of contaminants are coupled to studies on cycling of nutrients normally required by an ecosystem; this provides important information needed to develop scientifically sound measures for control of materials. For example, where a radioelement behaves like a plant and animal nutrient, it may be concentrated in certain food chains. Recent research results indicate that technetium, a radioactive fission product, behaves like sulfur and accumulates in plants, fowl, and ultimately in eggs consumed by humans.

Investigations on biological responses of ecosystems are carried out on communities of plants and animals, and populations of single species, and on single cells of plants and animals. This long-term research paid off when it was used recently to develop master maps showing different sensitivities of environmental units in the Arctic. Based on information on the maps, user groups can predict the ability of each landscape unit to handle stresses resulting from increased vehicle traffic, oil spills, or construction.

Long-term safe storage and disposal of contaminants from the extraction, refining, or combustion of fuels is a pressing problem, particularly in energy-rich regions of the country. An expansion of this basic portion of our program on cycling of materials in terrestrial systems will be made in FY 1984. It will focus on movement and fate of chemicals dissolved by water percolating through the ground, including the role of vegetation for sequestering possible contaminants in these waters. We will focus research on understanding metabolic processes which accumulate or eliminate metals in plants and animals.

Physical and Technological Research

This subprogram, for which $26.0 million is requested in FY 1984, constitutes the physical sciences component of the health and environmental research program. Analytical chemistry research under this subprogram identifies and measures chemical classes and compounds that cause biological activity in defense and energy-related materials. This subprogram also includes atmospheric science research aimed at improving our capability to describe how materials move through and are changed in the atmosphere. Finally, the measurement sciences activity develops improved radiation and chemical instrumentation systems as well as better techniques for assessing human exposure to defense and energy-related agents.

A key activity over the past few years has been to characterize chemically a variety of synfuels-related materials to determine which specific chemicals are responsible for producing biological effects in simple test systems. Through this research we have learned that the same types of chemicals are responsible for biological activity found in coal derived syncrudes and boiler fuels as well as gasifier tars. With this knowledge, we can confidently complete our chemical analyses effort in conjunction with short-term biological studies and in FY 1984 realign our research program to address long-term generic issues relevant to all coal conversion technologies.

In the atmospheric sciences area, research on acid deposition has produced the first comprehensive description of the distribution of major chemical species over the North American Continent. These descriptions display seasonal concentrations of calcium, ammonium, nitrate, sulfate, and hydrogen ions and show greatest deposition in the Ohio, Pennsylvania, West Virginia region. In addition, a series of models have been developed that predict spatial and temporal concentrations of various chemicals from power plants. These models will be tested to evaluate their capability and determine their limitations.

Another atmospheric science activity involves the study of long-range transport. Many regional air pollution models have been developed in the last few years, but until recently, there has been no way to verify them. The development of a series of non-reacting non-depositing gaseous tracers, the perfluorocarbons, which can be detected down to 2 parts in 10^{15} parts of air, now enables verification of model transport predictions over areas as large as the Northeastern United States.

The first full field experiments will take place later this summer during which six releases of the tracers from western Ohio and possibly Central Ontario will be measured at about 100 surface locations in the northeastern U.S. and Southern California. Aircraft will also be used to measure the tracer in the atmosphere. Since the tracer released from either of the two locations will travel over the Appalachian mountains, the experiment, which will continue in FY 1984, is called the Cross-Appalachian Tracer Experiment-1983 (CAPTEX-83). For the overall atmospheric dispersion question, this experiment is designed to separate the physical transport component from the chemical transformation component, and will enable a definitive evaluation of physical transport models.

Sponsoring CAPTEX-83 along with the Department of Energy are the National Oceanic and Atmospheric Administration, The Environmental Protection Agency, the Electric Power Research Institute, the Atmospheric Environment Service of Canada and the Provinces of Ontario and Quebec.

Nuclear Medicine Applications

Nuclear Medicine is the branch of medicine concerned with the use of radioactive and stable isotopes in biomedical research and clinical medicine. The Department fosters research in nuclear medicine by bringing together physicists, chemists, biologists, engineers and physicians to develop medically useful isotopes, isotope-labeled pharmaceuticals and instrumentation to the level where their clinical feasibility is established. Thereafter, these new technologies, instruments, and isotopic materials are taken over by the private sector for manufacture and distribution or by other agencies or institutions to be used for the study of specific diseases.

The development and application of nuclear techniques for diagnostic purposes has changed the practice of medicine. They have reduced the need for invasive procedures and exploratory surgery, made hospital stays shorter, less painful and less dangerous and have greatly expanded the physicians' arsenal in this fight against disease and human suffering. Our Nuclear Medicine Applications program, for which $21.0 million is requested in FY 1984, has played an important role in these developments and continues to do so.

Recently there has been much research emphasis on the production and diagnostic use of short-lived radionuclides. Medically these isotopes are useful because they decrease the dose of radiation to the patient. Other aspects are also important. For example, a collaborative effort between Oak Ridge National Laboratory and Children's Hospital in Boston is nearing the completion of an Osmium-191/Iridium-191m generator. Osmium-191 with a half life of 15.4 days produces a daughter, Iridium-191m, which has a half life of only 4.96 seconds. This allows tests to be repeated and validated rapidly with practically no radiation to the patient. Even more important, there is now perhaps a good non-invasive way to diagnose accurately suspected congenital heart problems in infants and children.

Concurrent with the development of short-lived radionuclides has been the growth of Positron Emission Tomography (PET), an imaging device. It provides an unprecedented capability to examine and measure the local biochemical and physiologic changes of the human body. The combination of computer based tomographic techniques and radiolabeled natural chemicals permits PET to be used as a safe, non-invasive biochemical microscope. The physician can look inside the human body and examine the life sustaining processes of body chemistry.

Research is also being conducted to develop neutron capture therapy for potential use in medicine. This type of treatment requires the incorporation of compounds labeled with boron into the tumor, and subsequent irradiation with neutrons. The boron atoms capture the neutrons, and in so doing, emit alpha particles which are extremely effective in killing nearby cells. Thus, the radiation dose is almost all concentrated in the tumor, producing no damage to surrounding healthy tissue. Recent developments in both boron chemistry and in our ability to develop cancer-seeking compounds have revived our interest in this method of treatment.

Carbon Dioxide Research

The Carbon Dioxide Research program is designed to develop a sound, quantitative atmospheric carbon dioxide knowledge base to aid in energy policy decision making. While funds for this CO_2 program are budgeted in the Biological and Environmental Research Program, the Office of Basic Energy Sciences manages the CO_2 program.

We must improve our understanding of the fundamental scientific relationships between CO_2 concentration and climate; this can only be accomplished by increased data collection, improved measurements, and development of reliable models. We can then answer questions with confidence about the relationships between future atmospheric levels of carbon dioxide, the magnitude of climate change and the responses of crops and ecosystems to higher CO_2 levels.

The FY 1984 budget request of $12.0 million will place additional programmatic effort on collecting and analyzing data on the effects of increased CO_2 levels on crops such as corn and wheat; expanding our research efforts on the first detection of CO_2 induced climate change; increasing research on carbon uptake in oceans; and participating in an international cloud climatology program that should significantly improve climate models.

The next program that I will discuss is the Magnetic Fusion Energy Program.

MAGNETIC FUSION ENERGY

The Department of Energy manages the Government's program that seeks to demonstrate the scientific and engineering feasibility of nuclear fusion. The Department's policy on fusion is to maintain a leadership role for the U.S. in the area of magnetic fusion energy research and development. This is being done by conducting a program of research involving various fusion plasma confinement concepts. During the next decade, it is expected that one of these plasma confinement concepts will be selected for further development as a power system. The Department also plans to develop the magnetic fusion energy technological base and transfer it to industry.

The goal of the Magnetic Fusion Energy Program is to develop the scientific and technological information required to design and construct magnetic fusion power systems. These systems should provide an effectively inexhaustible, environmentally and economically acceptable energy source for the future. The program is based on the fact that light nuclei such as deuterium and tritium will undergo nuclear fusion when they are caused to collide with each other at high speeds. This fusion reaction releases more energy than is associated with the speed of the colliding nuclei. To cause the controlled release of enough such energy to make a practical power system requires the creation and confinement of a hot ionized gas (plasma) at temperatures in excess of 100,000,000 degrees Celsius.

During the past three decades, the program has focused on the basic scientific and technological issues associated with the production, heating and confinement of high temperature plasmas in various magnetic field configurations. This phase of the program is entering its final period with the completion of the Tokamak Fusion Test Reactor (TFTR) facility at the Princeton Plasma Physics Laboratory. TFTR is designed to demonstrate the scientific feasibility of magnetic fusion energy release. The experimental program leading to this demonstration is expected to achieve energy breakeven by about 1986, i.e., the generation by fusion of as much energy as was required to heat the plasma. The TFTR attained its first plasma in December, 1982.

During the next decade, the program will emphasize the applied scientific research and technology development needed to produce practical fusion applications. Research efforts will concentrate on the two leading plasma confinement approaches, the long pulse tokamak concept and the tandem mirror concept, in parallel with associated engineering and development. It is expected that this effort will lead to the selection of one of the major concepts for use as the fusion plasma core of an advanced engineering development device needed for a full demonstration of engineering feasibility.

The Department's plan for developing fusion energy involves a three-phase program. The first phase will emphasize achieving scientific feasibility in the next few years. The second, or Product Definition phase, will concentrate on the selection of a reactor concept for further advanced engineering and technology development. The Product Definition phase will also include the design of an Engineering Test Reactor (ETR) aimed at demonstrating the engineering feasibility of fusion. The third, or Product Development phase, will involve the development of the data base needed for the commercial application of fusion power reactors.

The U.S. fusion program continues to make significant scientific progress. Presently, the tokamak is the most developed confinement concept followed by the more recently developed tandem mirror. Both are ready to attempt production of reactor-grade plasmas through the existing Tokamak Fusion Test Reactor (TFTR) and the Mirror Fusion Test Facility (MFTF-B), which is under construction at Lawrence Livermore National Laboratory. Several of the currently operating tokamak experiments have, in separate experiments, achieved reactor-level temperatures and near reactor-level confinement times and densities. TFTR and its possible upgrades will use deuterium and tritium fuel to provide an introduction to the physics and engineering problems likely to be encountered in a power-producing reactor.

In the mirror program, reactor level temperatures have already been achieved. The Tandem Mirror Experiment (TMX), also at Lawrence Livermore National Laboratory, has established the basic principles of the tandem mirror concept without thermal barriers. The TMX upgrade (TMX-U) will be the primary mirror device operating in 1983. In TMX-U the key scientific issues of the thermal barrier concept will be investigated. Thermal barriers are produced with microwave heating and neutral beam pumping to improve the operating performance of the tandem mirror by allowing hotter plasmas to be confined for a longer time and improving the plasma stability. Construction of the MFTF-B project is scheduled for completion in 1987. This device will investigate the physics and engineering principles of reactor-level tandem mirrors in much the same way that TFTR will do for the tokamak design. It is expected that plasma conditions approaching the equivalent of energy breakeven should be obtained using hydrogen and deuterium. Experience with near reactor size components, such as superconducting magnets and plasma heating systems, will also be obtained in these experiments.

In the advanced fusion concepts program, both the compact toroid experiments, conducted by laboratory, university and industrial entities, and the ZT-40 reversed field pinch experiment, at Los Alamos National Laboratory, achieved significantly longer plasma lifetime and higher temperature this year. In addition, a new process has been identified in these experiments, which may lead to much longer plasma duration than had previously been expected.

The fusion technology development program supports engineering research and development needed for practical fusion energy systems. The program has developed components and subsystems for ongoing experiments and is now working on critical components and technologies for next generation devices. Perhaps the best examples of work in the latter area are the development and testing of large superconducting magnets in the Large Coil Test Facility at Oak Ridge National Laboratory and demonstration of tritium handling technology in the Tritium Systems Test Assembly at Los Alamos National Laboratory. Some of the technology developed for these fusion programs, will undoubtedly find broader application.

Let me turn now to the details of the Magnetic Fusion Energy budget request. The President's request for FY 1984 is $467 million, an increase of $19.9 million over the FY 1983 estimate. The FY 1984 request includes $392.7 million for Operating Expenses, $37.8 million for Capital Equipment and $36.5 million for Construction (Tables 10 & 11). The FY 1984 request will support the scientific and technological development of the two mainline concepts, tokamaks and tandem mirrors, as well as further work on alternate concepts.

The Magnetic Fusion Energy budget request is shown by subprogram in Table 12. This proposed allocation of the total fusion budget will allow the program to conduct a balanced R&D effort focused on defining a practical fusion product for further development. As can be seen from this table the most significant change from FY 1983 is in the Planning and Projects subprogram where resources are needed for the fabrication of auxiliary components for the MFTF-B project. The other significant change proposed in the FY 1984 budget request is the termination of effort on the Elmo Bumpy Torus Proof-of-Principle project at Oak Ridge National Laboratory.

The FY 1984 budget request for Confinement Systems of $206.7 million would be directed at improved plasma performance and tests of critical plasma issues: higher temperatures, longer confinement time, higher magnetic efficiency, steady state plasma discharges and improved impurity controls.

The Toroidal Confinement Systems category budget will increase to $159.7 million. This will allow physics experiments to continue as planned on the

Table 10

Magnetic Fusion Energy
Budget Authority
($ in Millions)

	FY 1983 Estimate	FY 1984 Request
Operating Expenses	$ 361.6	$ 392.7
Capital Equipment	39.5	37.8
Construction	46.0	36.5
Total	$ 447.1	$ 467.0

Table 11

Office of Energy Research
FY 1984
Magnetic Fusion Energy
(B/A in Millions)

	FY 1983 Estimate	FY 1984 Request
Operating Expenses		
Applied Plasma Physics	$ 73.3	$ 76.0
Toroidal Confinement Systems	137.7	144.1
Mirror Confinement Systems	43.3	41.9
Development and Technology	74.3	77.4
Planning and Projects	29.0	48.7
Program Direction	4.0	4.6
Subtotal	$361.6	$392.7
Capital Equipment	39.5	37.8
Construction		
Mirror Fusion Test Facility-B	40.0	30.0
General Plant Projects	6.0	6.5
Subtotal	$ 46.0	$ 36.5
Total	$447.1	$467.0

Table 12

Magnetic Fusion Energy
FY 1984 Budget
Total Program Request
($ in millions; B/A)

	FY 1982	FY 1983	FY 1984
Applied Plasma Physics	72.9	77.3	81.1
Confinement Systems	155.4	202.8	206.7
Development and Technology	88.7	84.0	85.1
Planning and Projects	130.6	79.0	89.5
Program Direction	3.6	4.0	4.6
Total	451.2	447.1	467.0

continue as planned on the Princeton Large Torus, Alcator C (Massachusetts Institute of Technology) and Doublet III (Gulf Atomic Technologies, Inc., La Jolla, California). The Poloidal Diverter Experiment (PDX) facility at Princeton will be shut down by the end of FY 1983 and the Impurities Studies Experiment (ISX-B) at Oak Ridge National Laboratory will be operated until the completion of its planned experiments for FY 1984. While no new device fabrication projects are proposed, several will continue in FY 1984 including the provision of a new D-shaped vacuum vessel and additional electron cyclotron resonance heating power on Doublet III and the modification of the Princeton Large Torus facility for steady-state experiments. TFTR would be funded at the FY 1983 level for the first full year of experimental operations. While some preliminary information will be obtained from TFTR in FY 1983, higher power operation will not begin until FY 1984 when the the first two neutral beam systems will be installed.

A total of $47 million of the Confinement Systems request will support the Mirror Confinement Systems budget category including both the mainline tandem mirror program and the Elmo Bumpy Torus (EBT) alternate concept program. Both of these areas are aimed at producing a steady-state source of fusion power. The primary technical difference between these two mirror-based concepts is that the tandem mirror is a linear, open-ended system, while the bumpy torus is a toroidal closed system, but one which consists of many small mirror cells, linked together in series.

Of the several tandem mirror devices currently operating, TMX-U is the "workhorse" facility of the program, with large heating capability using microwaves and neutral beams. A facility called TARA, now being fabricated at the Massachusetts Institute of Technology, will provide a major test of axisymmetric design, the favored reactor approach for the thermal barrier tandem mirror. The TARA construction will be completed in FY 1984; funds also are provided to initiate experimental operations in FY 1984. Together these two machines (TMX-U and TARA) will provide proof-of-principle demonstrations of the key physics issues for thermal barrier tandem mirrors in the period FY 1983-1985. Supporting research efforts will continue to be provided from the operation of several smaller devices.

The EBT-S facility at Oak Ridge National Laboratory is the only operating bumpy torus device in the U.S.; it provides the experimental physics data in this country for this concept. A base scientific program will be maintained on this alternate concept using the EBT-S facility in FY 1984; however, a decision has been made to terminate the EBT-P proof-of-principle project in FY 1984. This decision is based on technical priorities within the overall budget.

The Confinement Systems subprogram, in conjunction with the Applied Plasma Physics (APP) subprogram, provides the physics basis for the fusion program. The budget request of $81.1 million for APP will allow continued support of these efforts. Theoretical programs in the APP subprogram seek to interpret and predict the results of confinement experiments and use this understanding for the design of improved experiments and reactors. Small experiments, a large portion of which are carried out at universities, will investigate specific issues of tokamak or mirror physics and also develop advanced diagnostic techniques for use in confinement experiments. APP experiments will also investigate concept improvements leading to potential compact reactor configurations such as reversed field pinches or compact toroids. These efforts also help provide a more complete understanding of the physics and technology data base for magnetic fusion. The final activity supported under this subprogram is the operation and maintenance of the MFE computer network. This integrated network provides for all the scientific and engineering computing needs for the entire fusion program and is operated via a satellite communications system.

The FY 1984 budget request for the Development and Technology (D&T) subprogram is $85.1 million. The goals of this subprogram are to (1) provide technology support to the major existing confinement devices; (2) to develop the critical engineering and technological basis needed for the selection of the best confinement and technology options for the fusion reactor plasma core decision and the Engineering Test Reactor decision; and (3) to support key long-term requirements for developing commercial fusion. As a result of the present strategy for fusion development, D&T efforts in FY 1984 will emphasize high priority work that supports reactor concept selection and technology feasibility questions. In carrying out these tasks, one of our objectives is to obtain significant participation by industry in fusion technology development to build the base that will be needed in order for fusion to be used commercially. The proposed funding level, which is about 1% higher than the FY 1983 level, provides for continued development in the areas of magnets, heating technology, materials, and system components.

The Planning and Projects subprogram, with an FY 1984 request of $89.5 million, is responsible for constructing major new facilities and conducting project specific research and development activities. General Plant Projects (GPP) and General Purpose Equipment (GPE) are also funded in this category. The major effort in FY 1984 is associated with construction of the MFTF-B project and fabrication of auxiliary components for this facility. Funding is also provided for continuation of the TFTR flexibility modifications to enable us to understand self heating of the plasma as a result of burning deuterium and tritium. The Fusion Materials Irradiation Test facility (FMIT) at the Hanford Engineering Development Laboratory will allow materials testing in an environment representative of an operating fusion reactor. It will also provide neutron fluxes several times that of a fusion reactor to allow accelerated end of life testing of fusion system materials. Although funding in the FY 1984 budget is provided to maintain essential FMIT activities, completion of the accelerator development in FY 1984 will depend on the international cooperation on the FMIT project.

International cooperation by various components of the U.S. fusion program has increased significantly during recent years. The major foreign partners are the European community and Japan, with selected scientific exchanges with the Soviet Union as well. Those cooperative activities include: sharing of research data, joint planning of comprehensive research programs in selected areas, joint funding of multi-million dollar projects in the U.S., and consideration of joint funding and operation of future major projects. If international cooperation were to become so extensive as to result in programmatic dependencies, a careful assessment of the consequences of this interdependence would be undertaken.

I will now describe the Energy Research Analyses, University Research Support, University Research Instrumentation and, the Multiprogram General Purpose Facilities programs. The FY 1984 budget request for these programs is shown in Table 13 following my discussion of the programs. Before I discuss these outlay programs, however, I would like to comment on the advisory responsibilities of the Director of Energy Research.

ADVISORY AND ASSESSMENT ACTIVITIES

In addition to his outlay program responsibilities, the Director of Energy Research carries out statutory advisory responsibilities in several areas. These include serving as the principal science advisor to the Secretary on energy R&D programs, oversight of the non-weapons multiprogram laboratories and the education and training of scientists and engineers. The Office of Energy Research also provides staff support to the Energy Research Advisory Board (ERAB) whose members advise the Secretary on the Department's energy R&D programs. The Board's membership includes representatives from industry, universities, energy users, state and local governments and public interest groups. ERAB reports directly to the Secretary of the Department of Energy with staff support provided through ER's Director of Science and Technology Affairs staff.

Within the Office of Energy Research, the Office of Field Operations Management (FOM) and the Office of Program Analysis (OPA) support the Director's advisory responsibilities. The Office of Field Operations Management supports the Director with regard to oversight of the laboratories and energy-related manpower development and training activities. This Office has developed several management tools used by the Department in administering its laboratories and R&D facilities across the country. It also continues to manage the University Research Support and the Multiprogram General Purpose Facilities programs, as well as the new University Research Instrumentation program, all of which I will discuss shortly. The Office of Program Analysis, on the other hand, provides energy research analysis support.

ENERGY RESEARCH ANALYSES

The FY 1984 budget request for Energy Research Analyses is $2.9 million. This program provides the Department with the capability for independent, objective analyses of its technical needs and opportunities. The functions of this activity include assessing the adequacy of the long-range (technology base) research that supports the Department's R&D programs; carrying out independent analyses and technology assessments of the agency's R&D programs; providing coordination and direction in interagency activities such as acid rain research; coordinating resolution of major technical issues and research policy developments; and providing support to agency advisory groups such as the Energy Research Advisory Board. The program is carried out by the Office of Energy Research through studies, workshops, panels and other mechanisms which allow the Department to make use of the best available scientific and technical talent from industry, academia and the National Laboratories.

There were a number of accomplishments in each of the program's functional areas during FY 1982-83. Recent assessments of the Department's technology base included a review by the Fossil Energy Research Working Group, an industry, academic and Government work group who defined R&D needs in shale oil, tar sands and heavy oil. Several program analyses were completed including an assessment of the Office of Energy Research's Basic Energy Sciences program, a review of the research objective of the Battery Storage Program that led to a shift in program emphasis and an assessment that clarified the potential benefit of ethanol as a transportation fuel for the Office of Alcohol Fuels. Recent coordination responsibilities for the Department were related to participation in the Interagency Task Force on Acid Precipitation, the Interagency Working Group on Strategic Minerals Policy and the Interagency Program Board on Civil Operational Land Remote Sensing from Space.

The FY 1984 budget request would provide for up to three technology assessments, depending on their complexity, and up to four program assessments. Research analyses would include assessment of the quantifiable accomplishments of research programs, such as the Office of Health and Environmental Research, and reviews of research that crosscuts agency programs (e.g., acid rain). Coordination activities related to acid rain and civil land remote sensing would be continued and support would be provided to the Director, Office of Energy Research on reassessments of the Department's R&D priorities, programs and technology base. Independent peer review of technical or research subjects requested by principal Secretarial Offices or the Director, Office of Energy Research would be supported (e.g., the Coal Combustion Research Working Group, an industry, academic and Government group, will define research needs in coal combustion by early 1984). Finally, advisory groups, such as the Energy Research Advisory Board, will continue to be supported.

UNIVERSITY RESEARCH SUPPORT

The FY 1984 budget request for the University Research Support (URS) program is $5.5 million. The goal of this program is to assist in maintaining strong, energy-related scientific and technical research capabilities at universities and the national laboratories. The URS program provides a budgetary and programmatic focus for specialized research and manpower development efforts aimed at securing top quality energy researchers and broadening the pool of experienced scientists from which Government, universities and industry draw. This is accomplished by:

- Using the unique resources of the Department's National Laboratories to assist in university faculty and student research and training;
- Maintaining and strengthening university based energy research and manpower development efforts in selected high priority research fields;
- Increasing the number of students pursuing professional level degrees in energy-related science or engineering;
- Enhancing the quality of the scientific/technical workforce in the Department's national laboratories and;
- Helping to expedite the transfer of university-based energy research to potential users in the private sector.

The URS program consists of two major subprograms: The University/National Laboratory Cooperative Research program and the Energy Manpower Development program. The first of these programs, University/Laboratory Cooperative Research has two elements, one on student/faculty training and the other on university reactor fuel assistance. The FY 1984 budget request for these activities is $5.0 million. Of that $5.0 million, $3.5 million is requested to support efforts that bring university faculty and students to the national laboratories and other government contractor facilities for research and training. In addition to training for the participants, these activities provide the labs with additional research capability. During 1983, it is expected that over 1900 faculty and student participants will be involved in URS-supported activities at 32 laboratories and contractor facilities.

The University Reactor Fuel Assistance activity, with an FY 1984 budget request of $1.5 million, provides funds to assist in the purchase of nuclear fuel and related support for university-based nuclear research and training reactors. These reactors are essential to the training of future nuclear scientists and engineers. Fuel for the reactors is fabricated under contract to the Department and then "loaned" to the participating universities for use. Partial support is also provided for the operational expenses of a number of the university reactors when they are shared with researchers at neighboring universities. FY 1984 will be the first year of full production by a new contractor for the fuel required by the higher powered research reactors. Up to six such reactors would be refueled during FY 1984 and 12 reactor sharing grants would be made on a competitive basis. Support would also be provided for costs associated with the transport of spent fuel to designated fuel recovery sites.

The second URS program, Energy Manpower Development, consists of two manpower-oriented efforts. The FY 1984 budget request is $0.5 million. The Manpower Assessment activity analyzes the supply and demand of manpower for both current and future energy R&D programs. The Energy Education and Training effort supports activities aimed at encouraging secondary school students to pursue energy-related science and engineering programs at the college level. The FY 1984 budget request would provide for continuation or renewal of prior year budget activities.

UNIVERSITY RESEARCH INSTRUMENTATION

The University Research Instrumentation program is an initiative proposed for FY 1984 as part of the combined public/ private sector effort to help alleviate the serious, national shortage of state-of-the-art, scientific instrumentation in the major research universities. The budget request is $6.0 million. The goal of the new initiative is to help universities strengthen their capabilities to conduct advanced, long-range research in specific energy R&D areas.

Direct access to state-of-the-art instrumentation often determines whether scientists can produce frontier-level results. However, the cost of the equipment is now so high that replacing obsolete equipment or obtaining new equipment is beyond the means of many research-oriented universities. The instrumentation required to study many energy-related processes and materials includes a variety of scanning microscopes, spectrometers, X-ray microscopes and diffraction equipment, laser diagnostic equipment, etc., each of which costs in excess of $100,000. A recent study by the Association of American Universities indicated that "the equipment used in the top-ranked universities. . . has a median age twice that of the instrumentation available to leading industrial research laboratories," with a large fraction of the equipment being obsolete.

During the last few years, the Department's national laboratories have been encouraged to increase the amount of time their research equipment is available to university researchers. Several unique, user-oriented research facilities (e.g., the Combustion Research Facility and the National Synchrotron Light Source) have also been established and are equally available to university, industry and laboratory researchers. Emphasis will continue to be placed on the cooperative use of existing equipment and facilities. However, a significant level of university research involves a large number of researchers (both faculty and students) who require continued access to certain instruments. In such instances the equipment must be available on-campus. Although the Department provides a small amount of support for research instrumentation on-campus, such instruments generally cost on the order of $35,000 or less and do not have the capabilities of the sophisticated instruments referred to above.

The University Instrumentation initiative would focus on university research groups with experience in designated research areas (e.g., combustion, biological energy conversion, catalysis, radioactive waste management, engineering research, etc.) of primary concern to both basic and technology-oriented energy research programs. Those groups supported would be assisted in obtaining the additional sophisticated instruments, each generally costing in excess of $100,000, which would enable them more effectively to conduct advanced research in the designated program areas. Awards would be made following a national competition based on such criteria as the merit and accomplishments of the institution's current applicable energy research programs, the potential for expanding and/or improving these programs if the new instruments where available on-campus, the institution's experience in planning for and using other major research equipment, the availability of similar instrumentation at nearby institutions, the institution's commitment to energy research and its plans for meeting and sharing the total costs associated with the instrument(s).

The $6.0 million requested in FY 1984 would enable some 20 to 30 university research groups to obtain some of the special research equipment they require to improve their capabilities to conduct energy research. A special interagency committee reporting to the President's Science Advisor, and chaired by the Director of the National Science Foundation, will provide overall policy guidance and ensure effective coordination of this and other agency research instrumentation efforts.

MULTIPROGRAM GENERAL PURPOSE FACILITIES

The FY 1984 budget request for Multiprogram General Purpose Facilities (MGPF) is $40.6 million (Table 14). The program's goal is to rehabilitate and replace multiprogram general support facilities that are essential to continued operation of the laboratories. These facilities include roads, railroads, site utilities and support buildings such as laboratories, office buildings and warehouses. The MGPF program is managed by the Office of Energy Research for the Department.

The major multiprogram laboratories and other Department of Energy sites included in the program received over $3 billion in FY 1982 to carry out research programs in nuclear energy, fusion, basic energy sciences, high energy and nuclear physics, life sciences, solar energy, fossil energy and conservation. During stringent budget years it is often tempting to postpone necessary replacement or rehabilitation of deficient facilities in favor of maintaining a maximum amount of program effort in these research areas. We have learned from the experience of our predecessor agencies that such expediencies lead to negative impacts on the very programs they are aimed to protect. Equally important, they also result in an inventory of billions of dollars in corrective measures which some future generation will be expected to undertake. We plan, therefore, to continue the MGPF program, which began in FY 1981, as a necessary cost of doing business as long as the multiprogram laboratory facilities are utilized to perform research and development functions for the agency.

The FY 1984 budget request would continue construction of nine projects started in prior years and would initiate four critical projects: rehabilitation of Old Town area utilities, LBL (TEC $4.8 million); Cooling Water Facility, ORNL (TEC $4.0 million); road repairs (various sites - TEC $16.0 million) and a Facilities Support project (various sites - TEC $4.0 million). The Facilities Support Project provides for much needed facility-related improvements at several sites that are in the $1-2 million range. Projects in this size range are too large for traditional General Plant Projects funding and are too small and numerous to qualify for separate line item status.

ADVISORY AND OVERSIGHT PROGRAM DIRECTION AND POLICY AND MANAGEMENT

The FY 1984 budget request for Advisory and Oversight Program Direction is $3.4 million. These funds are required to provide for the salaries, benefits, travel and other expenses associated with 44 full-time equivalents. This FY 1984 request would provide staffing resources required by the Director of Energy Research to carry out his responsibilities under legislation (P.L. 95-91) and those mandated by the Secretary in areas beyond the scope of ongoing Energy Research programs.

The FY 1984 budget request for Policy and Management is $0.5 million. These funds are required to provide for the salaries and related expenses associated with 8 full-time equivalents in the Office of the Director of Energy Research and the Office of Management.

Mr. Chairman, this concludes my testimony. I would be pleased to answer any questions at this time.

Table 13

Energy Research Analyses, University Research Support, University Research Instrumentation, Multiprogram General Purpose Facilities
Budget Authority
($ in millions)

	FY 1983 Estimate	FY 1984 Request
Energy Research Analyses	$ 2.8	$ 2.9
University Research Support	6.0	5.5
University Research Instrumentation	-	6.0
Multiprogram General Purpose Facilities	34.0	40.6

Table 14

Multiprogram General Purpose Facilities
Budget Authority
($ in millions)

	Prior Years	FY 1984 Request
Construction		
84-ER-101 Rehabilitate Old Town Utilities, LBL	0	1.0
84-ER-102 Cooling Water Facility, ORNL	0	0.6
84-ER-103 Road Repairs, various sites	0	3.0
84-ER-104 Facilities Support, various sites	0	4.0
Prior Year ongoing projects	34.0	32.0
Total	34.0	$40.6

Senator **Domenici**. Thank you very much, Doctor. Let me jump around a bit, but I do want to compliment you on your request for a multiprogram facility upgrade. I know that this is not a glamorous part of the budget, but I think you are to be commended because we just can't continue to let our laboratories deterioriate.

Let me be somewhat parochial on this issue just for a moment and ask you if the request for the energy technology lab at Sandia includes the funds for the third component of that project? That is the technology center.

I believe the record was quite clear about building the entire project as originally proposed. Could you elaborate on that?

Dr. **Trivelpiece**. My understanding is that that will go forward as you are indicating. We will need a minor reallocation of funds within the requested total for multiprogram general purpose facilities to accomplish this.

Senator **Domenici**. Fine. On the matter of technology transfer, it has come to my attention that it is not very easy for our people in the field to distinguish between U.S. companies who desire information so that they can use it in this country or if they are just trying to cover for a foreign interest in what seems to be our rush to share the knowledge of our labs within industry.

There is some more than suspicion on the part of some of our people that we are sharing it with our competitors almost more readily and more easily than we are with our own companies. I believe that you are in charge of the technology transfer program. Could you explain how it works and what the guidelines are that are available for people in this field and are the U.S. companies that are requesting information required to disclose if they are truly domestic companies or corporations or not?

Mr. **Trivelpiece**. I don't believe such disclosures are required. As you know, it is one of the dilemmas of a free society that you can either have information that is classified or not classified. It is difficult to have an intermediate category, and indeed if we make the information publicly available, then it is basically available to all, including potential foreign competitors.

We have not worked out a practical method by which we can distinguish between U.S. companies and non-U.S. companies in these circumstances. It is certainly a dilemma. We are doing everything that we can to encourage the rapid dissemination of technical information from our laboratories to our industrial companies, but in so doing we don't have a simple means of preventing that same information from being universally available to everyone.

Senator **Domenici**. I wonder if you might explore whether it is legitimate under existing law to merely make that inquiry? I see nothing wrong with asking those that do inquire to make a statement as to who they are inquiring for, if for no other reason than for us, for you to find out over the passage of time what kind of business entities are using the information.

Could you check into that? In other words, when they make the official inquiry, if it is ABC, Inc., U.S.A., that they merely say for whom they are seeking the information; could you ask that?

Dr. **Trivelpiece**. That is difficult to do. A large portion of the information requests don't come in a form which I think your question implies. They come simply by virtue of the fact that people receive information from the Technical Information Center at Oak Ridge. They are regular subscribers to the entire collection of information that is distributed so if one of the laboratories decides to take one of its technical achievements, put it into a report and submit it to the Technical Information Center, then it is basically a public document that can be obtained by anyone without any particular record of who it is that is receiving it. We do have, however, information on subscription lists of people who receive information from the Oak Ridge Technical Information Center.

I don't believe that you could perform an audit trail and it would be very difficult for anyone to identify whether or not a particular piece of information went to a particular company.

Senator **Domenici**. Do you have an impression as to whether our free world competitors are as accommodating with reference to new technology availability as we are? I mean I understand there in my home State that the technology center is a fabulous institution. We put it all in one place and we have a lot of our people there to explain it and define it, and we have visitors by the scores from the free industrial competitors.

Are there comparable facilities in Japan and Germany and France?

Dr. **Trivelpiece**. I am not aware of any particular facility per se, but certainly we do get information from other countries. It depends in particular on the scientific and technological areas involved. The fusion program for instance, is probably an example of where the transfer between us and the Soviet Union has worked to our mutual advantage. Probably in the situation with respect to computers and the Japanese Government it has not particularly worked to our advantage. So, you have to pick a specific area and get into the details with respect to it.

Senator **Domenici**. Senator Melcher, if you have any questions just interrupt me. We have about another 5 or 6 minutes and I will be through.

Senator **Melcher**. I have been thoroughly enlightened by your questions and the responses.

Senator **Domenici**. Are you all right for 5 or 10 minutes?

Senator **Melcher**. I sure am.

Senator **Domenici**. On biological and environmental research, Doctor, the budget has been declining with the consent of Congress I might add. My impression is that you have been allocating these cuts in a rather, an almost across-the-board manner. If I am wrong on that I stand corrected, and you do that, but if we are doing that, if we are to cut further, wouldn't it be appropriate for us to start through that system and establish some priorities rather than what appears to me to be a kind of a willy-nilly across-the-board approach?

Dr. **Trivelpiece**. I agree there has been a tendency to make these cuts across the board. Just this last year I was concerned with this problem as you are. I personally went on a tour of six of the facilities—Oak Ridge, Argonne, Livermore, Berkeley, Inhalation Toxicology Research Institute facility in Albuquerque, and Los Alamos. That four was made in preparation for reviewing the entire program with an eye to whether or not it would be appropriate to try to redefine things in such a way so that there were several healthy elements in these times of budgetary stringencies it is not prudent to simply continue all of these activities with small erosion at the margin of all of them.

It is my intention to carry out a review which would lead to identification of healthy elements in the program which should be protected well, and, to try to eliminate programs at the margin.

Senator DOMENICI. I would hope so because I don't see any immediate future acceleration in funding and I would think that obviously if Congress went along with some significant cuts they must have thought there was not as much need and that there was a lot of duplication between your efforts and some others, including EPA's, in accounting for the cuts, but that probably doesn't mean that scientists ought not allocate in some way and inform us as to which ones that we really ought to fund top dollar and which ought to be cut more.

Dr. TRIVELPIECE. Lest you put words in my mouth, I think this is a very important program and there are elements of it that are unique. One part of the strategy that the Atomic Energy Commission built into the system has led us to try to understand what the harmful aspects of nuclear radiation are in order to establish appropriate safeguards.

The other part of the strategy was to try to discover the beneficial uses of nuclear energy, that has led to the entire nuclear medicine industry which is an enormously beneficial thing to the United States. So these programs are very important. The fact that under the present budgetary circumstances our requested level of support has decreased in no way diminishes in my view of how essential these activities are.

Senator DOMENICI. Doctor, in your testimony you mentioned the new subatomic particle, the W particle, that was discovered in Europe.

I personally was a bit surprised to hear the response of some of our most noted physicists. A number of them attribute this discovery to the fact that the U.S. funding for high energy physics has been decreasing.

I don't believe that is the case. Perhaps you could give us your opinion and clarify that for the record. It is my impression that the United States is suffering from what I might call indecisiveness and maybe that has to do with fiscal policy, maybe not. Testimony before this subcommittee in the past has indicated that our scientific community is to a great extent following the progress of their competitors and that we hope to beat them in the near term.

Is there any effort within that group of scientists who set our goals in this area to focus on some bold new initiatives? I believe this administration and the Congress would be receptive to a proposal that would launch us into the next generation of research in high energy physics. If that next step is even more sophisticated and larger particle accelerators than the ones we now operate, I think there would still be a genuine interest.

What kind of research could we be doing to prepare for that and are we? First you might say my premise is wrong if you like.

Dr. TRIVELPIECE. You were very charitable in the use of the word "surprised" at the response of some U.S. scientists with respect to discovery of the W particle.

My assumption would have been that they simply would have congratulated their European colleagues and been done with it. The fact is that the team leader of that group, Carlo Rubbia, is a professor at Harvard University, so it is hard to say that the United States somehow did not participate in that discovery. The discovery of such a particle is not a single investigator event. It was a team of a rather large number of physicists from several countries that utilized a large facility in order to bring that off.

You also ask what are we doing about the future with respect to other facilities? As you know, we have a panel that is called the High Energy Physics Advisory Panel. They meet periodically to provide the Department with advice and guidance on where they think that area of science should be going. A subpanel, called The Woods Hole Panel, is now beginning a reivew on the subject of the long-range needs for facilities. They met for the first time last Friday. Dr. Keyworth and I both met with them and discussed with them our views on the need for a well-developed, long-range plan for where the high energy physics community is going and what kind of facilities are needed and the need for the panel to be objective in their scientific determinations to bring forward an appropriate plan.

They should complete this effort some time in the middle of the summer in time we hope if appropriate for any 1985 budget actions to be taken into account by the Department. The main thing is that they should, as you are suggesting, carefully examine what are the areas of physics needs, what are the important things to be looked at, what questions need to be answered and what facilities will be needed to answer those questions and try to come forward with some clear and unambiguous proposals.

They obviously have just gotten started and I don't know what their final answers are going to be, but we will keep you informed.

Senator DOMENICI. Are they enthused about this from what you can tell?

Dr. TRIVELPIECE. I think they are a little bit awed at the fact that they are taken seriously and the fact that what is important is to define whether or not a new facility is needed, and that the administration would be willing to entertain proposals from them. Enthusiastic certainly, but I think, as it is with most of these circumstances, that they must make hard choices. These are always a little bit frightening, because that usually means that some of the scientific community will receive and some will lose. That creates a certain amount of internal dissension, but I believe that they will come through with balanced recommendations or at least I hope they will come through with balanced recommendations. It is very important that they do so.

This particular scientific area has about the highest per capita support of any area of science in the United States, so I find it a little bit disconcerting that they believe that they have not been treated well as you implied by your concern.

Senator DOMENICI. Senator Ford, did you want me to yield to you or go to Senator Melcher?

Senator FORD. That would be fine. He was here first.

Senator DOMENICI. Senator Melcher.

Senator MELCHER. Thank you both. Mr. Trivelpiece, I would like to know a little bit more about magnetic fusion other than what is here in your testimony, in your prepared statement.

First of all, there is $462 million or $466 million in the budget for this?

Dr. TRIVELPIECE. $467 million is the fiscal year 1984 request.

Senator MELCHER. $467, we spent it in two places—Livermore and Princeton, right?

Dr. TRIVELPIECE. No sir, those are the two places which receive the largest amount of funding. However, the program involves participants from universities and industry and national laboratories and funds are certainly not spent in only these two places.

Senator MELCHER. Well, what are the other places?

Dr. TRIVELPIECE. The major locations are Oak Ridge National Laboratory, GA Technologies, Idaho National Engineering Laboratory, Oak Ridge, Berkeley, Los Alamos, MIT, the University of Wisconsin, the University of Texas, and many other commercial and university contractors.

Senator MELCHER. How much in each place?

Dr. TRIVELPIECE. There are so many that I would have trouble remembering what the budget is at each location. I would be glad to supply it for the record.

Senator MELCHER. Out of the $467 million, it seems to be indicated here that most of it would be at Livermore and Princeton.

Dr. TRIVELPIECE. Princeton is somewhere on the order of $134 million annual budget.

Senator MELCHER. And Livemore?

Dr. TRIVELPIECE. About $109 million at Livermore.

Senator MELCHER. Los Alamos?

Dr. TRIVELPIECE. One, five.

Senator MELCHER. One point five?

Dr. TRIVELPIECE. About $21 million.

Senator MELCHER. Oh, 21; and Oak Ridge?

Dr. TRIVELPIECE. About $67 million.

Senator MELCHER. And you said General what?

Dr. TRIVELPIECE. General Atomic Technologies Corp. in San Diego.

Senator MELCHER. How much there?

Dr. TRIVELPIECE. About $38 million.

Senator MELCHER. Would you say some of the Tokamak concept is present at all these places?

Dr. TRIVELPIECE. No. The Tokamak research is primarily concentrated at Princeton Piasma University, Princeton Plasma Physics Laboratory, the facility at Oak Ridge National Laboratory, and also some facilities at MIT.

Senator MELCHER. For Tokamak?

Dr. TRIVELPIECE. Yes.

Senator MELCHER. So it is confined to these?

Dr. TRIVELPIECE. General Atomic has a facility which is at San Diego.

Senator MELCHER. Is that Tokamak?

Dr. TRIVELPIECE. Yes, sir.

Senator MELCHER. All right. Then for Livermore and Los Alamos?

Dr. **Trivelpiece**. Livermore has the magnetic mirror confinement system concept, and Los Alamos has the high density plasma concept.

Senator **Melcher**. So we have got three concepts we are working on simultaneously?

Dr. **Trivelpiece**. There are two principal ones, the Tokamak and mirror.

Senator **Melcher**. Could there be more?

Dr. **Trivelpiece**. Oh, yes, there could be.

Senator **Melcher**. That we are working on right now?

Dr. **Trivelpiece**. I am not sure of the nature of your question.

Senator **Melcher**. Could there be more than three different concepts that we are working on right now?

Dr. **Trivelpiece**. There are, but they are not major concepts.

Senator **Melcher**. Would they be major enough to get $10 to $12 or even $25 million?

Dr. **Trivelpiece**. Certainly in the $10 million category, yes.

Senator **Melcher**. What year? What would be your feeling? You say hopefully in a decade you will get something laid down to share the technology with private industry. What would be your estimate then on generating a kilowatt or two of electricity? What decade?

Dr. **Trivelpiece**. That involves some speculation which I am a little bit loath to make in terms of when electricity will be generated for this particular process.

We have just started the Tokamak fusion test reactor facility at Princeton. That device when it reaches its full operating capability should be the first device that demonstrates that you can create the conditions in a plasma that illustrate whether or not you can get more energy back than was invested in creating the plasma.

Once that step takes place, then I think you can imagine different arrangements by which you could go to industrialization or commercialization or whatever.

Senator **Melcher**. I just asked you to speculate. Would 50 years be good speculation?

Dr. **Trivelpiece**. Well, it becomes somewhat of a self-fulfilling prophecy. It depends on the degree to which it is desirable or appropriate to commit funds and/or the need for it to be done. It could be done very rapidly if one were willing to change the U.S. science and technology enterprise in such a way that you devoted a great deal of effort to fusion.

On the other hand, given the present world circumstances with respect to oil and other forms of energy, it is not clear that the need is there to proceed in as rapid as possible mode a pace somewhere between those seems appropriate. The balance, the technical approach at the present rate is likely to lead to a scientific feasibility demonstration in the next few years. At that point there is then a systematic approach to develop that into a core plasma reactor concept that could be further developed and made commercial.

I have no way of forecasting whether or not if it were to be successful scientifically and it were to be successful in an engineering sense whether or not U.S. utilities would accept it or want it or whether or not 15 or 20 years from now it would even be needed. I assume that it will be. I think this is an appropriate thing for the

United States to continue supporting vigorously, but you are asking the question in the mode of what can be done.

The mode that I am trying to answer the question in is at the moment we are proceeding with a program that is systematic and balanced. It will lead to the answers to the kind of questions you are talking about in 10, 15 years.

Senator **MELCHER**. The kind of questions I am asking might be answered in 10 or 15 years?

Dr. **TRIVELPIECE**. No; your questions can be answered now, but the answers to the technical questions won't be available until then.

Senator **MELCHER**. You have got $19 million through a budget increase, through a budget process that has wrung out almost everything else. Now I find that rather unique.

Have you got anything more under your surveillance, under your guidance, that has gotten an increase of this size?

Dr. **TRIVELPIECE**. Yes; we are starting a construction program for the Stanford linear collider at Stanford University for $40 million. This project is in the high energy physics program.

Senator **MELCHER**. Is that a $40 million increase?

Dr. **TRIVELPIECE**. It is a $40 million beginning of construction for this year, for 1984.

Senator **MELCHER**. What is it for?

Dr. **TRIVELPIECE**. It will build on the facility that is located at the Stanford Linear Accelerator Center. The new facility is called a linear collider. It takes the electrons and positrons from the 2-mile long linear accelerator and causes them to be directed in head-on collisions in a way that will create this new W particle that was being mentioned as you arrived.

Senator **MELCHER**. Well then, we have got $467 million in this budget. How much was it in the last one? $19 million?

Dr. **TRIVELPIECE**. The fusion program request for fiscal year 1983 was $444 million.

Senator **MELCHER**. How much was appropriated? That amount?

Dr. **TRIVELPIECE**. The present funding level under the continuing resolution is $466 million.

Senator **MELCHER**. So a quarter million was added to that for the appropriation, and that is what your budget request is.

Now this will work on the major problem of how you confine hot plasma at temperatures in excess of 100 million degrees Celsius?

Dr. **TRIVELPIECE**. Yes.

Senator **MELCHER**. And is that about as hot as the inside of the Sun?

Dr. **TRIVELPIECE**. No; it is quite a bit hotter than the inside of the Sun.

Senator **MELCHER**. It is hotter than the inside of the Sun, so what you are really going to do in this in the next decade or so is to find out whether theoretically you can handle something that is hotter than the inside of the Sun?

Dr. **TRIVELPIECE**. Practically; we know theoretically you can do it. We must demonstrate practically whether or not it can be done, although the expectation is that it can.

Senator **MELCHER**. Would there be any radiation problem?

Dr. **Trivelpiece**. The output of a fusion reactor is mainly neutrons. The neutrons are then permitted to be absorbed by material and generate heat which then generates steam and presumably can then generate electricity.

Yes, there is radiation that is emitted by it—gamma radiation, X radiation, neutrons, and light.

Senator **Melcher**. So we would have two problems, the problem of confining the radiation and the problem of confining the light? The light would be blinding?

Dr. **Trivelpiece**. Well, you wouldn't look at it. The problem is not of confining radiation. Radiation is the source of heat.

Senator **Melcher**. Would the light be blinding? It would, would it not?

Dr. **Trivelpiece**. It depends on the plasma conditions. If you have a very high temperature plasma, it emits no light whatsoever.

However, there is always some edge to the plasma. Somewhere at the edge there is low-temperature plasma and gas. That would radiate light. Whether or not that light would be blinding or not I would have to make some calculations. I suspect that it would not be. However, it would be very unhealthy to be standing close to this thing.

Senator **Melcher**. The first page of your testimony lays out the overall need on the overall desire to pursue this technology, and I am not faulting you for having the desire to pursue it.

My questions are based on whether it is practical to spend $466 or $467 or even $400 million to pursue probably four or five different concepts simultaneously to see whether or not we might some time in the future find it desirable to go into this type of technology for the generation of electricity.

If you get somewhere, it might provide energy in an inexhaustible supply. I want to take you back to the reality. We are looking for how best to use an inexhaustible supply of coal over the next 200 years.

Now we know we can't possibly consume coal that is available to the United States in 200 years. Would you agree?

Dr. **Trivelpiece**. I am not sure what the resource for coal is, but that sounds consistent with what I have heard.

Senator **Melcher**. I will throw out this figure of 400-plus billion tons available in the United States that can be mined and used and we use about how much annually over a billion?

Senator **Ford**. Less than a billion.

Senator **Melcher**. We are using less than a billion. I think there might be reason to use more, so it is conceivably, well, from a practical standpoint if you have got an inexhaustible supply of coal available over the next 200 years and we like to use it better and yet we find that we have virtually no R&D money in the budget for better utilization of coal, and so I want to return to how we get to where this technology, magnetic fusion, some time in the future, maybe 50, 60, 70, 80 years or whatever, if it is desirable, how we are going to fund it? And I would suggest that perhaps this budget R&D is completely out of all of the entire realm of commonsense.

We are cutting the budget everywhere because our needs are so pressing this year, next year, the year after, the year after that, and then the year after that. We are looking at tremendous deficits and we don't seem to be doing anything about the near-term improvement of energy resources, particularly coal.

I am going to talk specifically now about MHD which you have zero budgeted in your request, is that correct?

Dr. **TRIVELPIECE**. That is in the fossil energy program. I have no personal responsibility for that.

Senator **MELCHER**. You are going to be in it because there is going to be some real tough scrutiny in this committee and I trust on the Senate floor, I feel fairly confident on the Senate floor, of why we are cutting back so much in R&D for coal and yet we seem to be able to come up with the same amount for this program, magnetic fusion, plus $1 million.

On MHD, to paraphrase your first two pages here, we are looking at a plasma, using a coal, heat it into a gaseous form of plasma, and burning it in a magnetic field at somewhere around in excess of 2,000° F, and one of the problems they are having is how to handle those temperatures and what materials to use.

Would that be about 1,000° Centigrade or Celsius?

Dr. **TRIVELPIECE**. It is a few electron volts; 10,000°, but it depends on the precise mode in which the MHD generator is being used. I think the one that you are referring to would probably be a few thousand degrees.

Senator **MELCHER**. Fahrenheit or Celsius?

Dr. **TRIVELPIECE**. Centigrade; turbine temperatures tend to run around 3,000° F. Plasma temperatures may be 5,000°. You can certainly have higher or lower temperatures, depending precisely on how you see the channel flow and so on.

I am not precisely certain with regard to coal-fired MHD generators what plasma temperatures would result, but they could be in the general vicinity of a couple of thousand degrees to 5,000°.

Certainly experiments that run at higher temperatures—the Russians, for instance, did run shock-tube experiments at their facility in which they used 20,000° plasma and got very efficient energy recovery with it.

Senator **MELCHER**. You mentioned the transfer of information was good between the United States and Russia. I am paraphrasing that. The transfer of information between the United States and Russia on MHD seems to be going along fairly well.

You said the transfer of information between the United States and Japan on magnetic fusion wasn't too good?

Dr. **TRIVELPIECE**. I don't believe I said that.

Senator **MELCHER**. Did you not? Maybe I misunderstood.

Dr. **TRIVELPIECE**. I was referring to the computer industry. In fusion there is transfer of information. Now the Japanese certainly have a program in magnetic confinement fusion and, in fact, that is one of their top priority national goals.

They are building an experiment that has some similarity to the experiment that has just been put online at Princeton. It is called JT-60, meaning it is 60 cubic meters of volume inside the confined toroidal plasma. They are moving forward. There is good exchange. We have a protocol with them. Their scientists work on the experiment that is at General Atomic and our scientists have joined with them in certain joint projects.

Senator MELCHER. The transfer of information then between both countries, Russia and Japan, is good in this field?

Dr. TRIVELPIECE. Between us and the Soviet Union, between us and Japan and also between the United States and the European Community; fusion has been quite an international activity. I think the technical field has benefited substantially by virtue of the fact that there is good communication among all parties.

Senator MELCHER. Are they pursuing these various different configurations, different theories?

Dr. TRIVELPIECE. The European Community? Yes, sir.

Senator MELCHER. And Japan also?

Dr. TRIVELPIECE. Yes.

Senator MELCHER. About four or five different concepts?

Dr. TRIVELPIECE. It is a balanced program, although there is certainly some degree of similarity in facilities between countries. There is some determination that each nation not pursue an identical program with that of other nations, so you have to look at some of the technical characteristics of the facilities to appreciate this, but if you look at it in detail, they really are not directly competitive and duplicative.

Senator MELCHER. Well, just to sum this up, something has got to give in the R&D budget if we are going to have any money for near term coal R&D, and this may be one of the areas that is going to have to be reduced.

Would you supply this committee and myself what your priorities are in this $467 million so that we can evaluate how we have some money available for some near term coal R&D, including MHD which the Department has zero budgeted? I won't say you; the Department.

[The requested information follows:]

FUSION PRIORITIES

Although the fusion program has clearly defined priorities, it would be extremely difficult to prepare a prioritized list of research topics with corresponding dollar values. If program levels are reduced, the entire program must be rebalanced—some tasks would be terminated, others slowed, and some left unchanged. Unless the precise amount of the decrease is known, it is difficult to predict how individual projects will be affected.

In general terms, our program priorities would be as follows: First, we would reduce our efforts on alternative concepts, engineering studies and technology development. Second, we would slow the pace of the mainline projects, TFTR and MFTF-B, although it is probable that a mixture of these two approaches would be likely in a given situation.

Further reductions would require restructuring of the program, and would reduce its mission focus. It is clear that at some point, the program would no longer be the balanced national effort to which the Administration has given high priority.

Dr. TRIVELPIECE. You realize that the administration has tried to support long-range and basic research and has put its emphasis there, and has chosen not to emphasize some of the near term technology development.

Senator MELCHER. We understand that, but we are grappling with these budgets and are trying to figure out in the near term how we come up with another 50 to 100 million for fiscal 1985, for instance, fiscal 1986, and something has got to give, and we don't seem to be able to add on. We have to show where we do what is practical and necessary in the near term so we can survive economically into the nineties and into the century, in 2000.

Thank you very much, Mr. Chairman.

Senator **Domenici**. Senator Ford.

Senator **Ford**. Thank you, Mr. Chairman, Mr. Trivelpiece. I will not take but just a moment of your time and the committee's.

You have made a very interesting statement early on after I got here based on the funding, that the world energy situation didn't lend itself to acceleration of some of these research or research and development programs.

It seems that we are back in the same situation we were earlier. We are just waiting to react again instead of acting as we should to move forward, so I would hope that at some point we could begin to act.

In your statement on page 36 you refer to acid rain, and page 39, CO_2.

Do you have anything you would like to add to our acid rain situation? Like we are in the movie business and some other things out there. It has become an international problem as it relates to us and Canada. Oh, I guess the TV programs I have seen on the weekend refer to the Midwest, particularly Ohio, some other things.

We are talking about $200 million fluidized bed operation at one plant. That would retrofit many of our plants and we cannot find the funding to go ahead, and we have got about $150 million of it from private sources and State governments, so it seems to me we ought to be moving.

That is near term. I think we ought to have both long and near term on board. I am not opposed to long term research and development, just the amount.

Would you like to add anything to your statement on page 36 and 39 as it referred to acid rain and CO_2?

Dr. **Trivelpiece**. The Department has some lead responsibility with respect to CO_2, and we have requested $12 million in fiscal year 1984 for research on CO_2. That would continue the program of trying to understand where it comes from, how it gets where it is going and where the sinks are in the system and what the influence, potential influence, is likely to be on the climate.

The rate of the increase of CO_2 in the atmosphere has diminished slightly and so the picture of a few years ago that the doubling time was going to be less than 50 years I think has been modified. The doubling time is now likely to be well in excess of 100 years if we continue fossil fuel usage at the present rate. However, other trace gases, such as methane and freons, also have a greenhouse effect and are increasing.

Under those circumstances, I think we do have adequate time to carry out a systematic program with respect to CO_2 to try and understand its impacts. It is not a near-term problem, and we believe that the $12 million we are requesting for our portion of the activity is appropriate.

Acid rain is probably a somewhat more complicated problem in that the mechanisms by which the sulfur and nitrous oxides get into the atmosphere, how they are transported in the atmosphere, and how their chemistry is modified by the atmospheric processes are all as yet poorly understood. We need to have a clearer picture of what happens when these do return to Earth in terms of what they do to the various fauna and flora. It does take some research to understand these things.

You mentioned the situation with respect to Canada. I think it is important that we and the Canadians have an adequate picture of the amount of acid deposition that is coming down and where it is coming from before any mitigation strategies are put into place.

I don't believe that we and the Canadians have a common scientific protocol by which we agree to make the measurements and what these measurements mean. I would urge and encourage that we try to establish with them common measurement methods and common protocols and common laboratories at which the particular samples are measured in such a way that we can come to an agreement as to what the scientific issues are before getting over into the political arena. It seems to have migrated into the political arena before the scientific study has been completed.

Senator FORD. You mentioned nitrogens, and I think that's right, and most people when they are referring to acid rain, refer to sulfur.

Dr. TRIVELPIECE. Yes.

Senator FORD. What is your interpretation?

Dr. TRIVELPIECE. It turns out that sulfur is one of the leading components that produces the acidic condition, because of the hydrogen ions that are available. There are some chemistry studies, however, which indicate that nitrous oxides may be a rate-determining or rate-limiting catalyst in terms of the amount of sulfur that is converted over into an acid form in the clouds. Therefore, the amount of nitrous oxides that are put into the atmosphere may have some bearing on the amount of sulfur acid that comes back.

Senator FORD. Bearing on the basis that it improves it?

Dr. TRIVELPIECE. No—on that it limits it. If you have a situation in which clouds are presumably saturated with sulfur in water droplets, then the amount of sulfur that gets converted to an acidic form depends on the simultaneous presence of nitrogen. If you increased the amount of nitrogen, you would then increase the amount of sulfur that gets converted to acid.

Senator FORD. So-called acid rain?

Dr. TRIVELPIECE. Yes.

Senator FORD. I have had a fleeting interest in all of this, and I happen to come from Senator Melcher's position as it relates to coal. I represent Kentucky, the largest coal-producing State in the Nation. They are closing in on us from other States. Their Btu in coal is somewhat less. The sulfur is also somewhat less.

It appears that your mirror confinement systems and mirror fusion test facilities have a reduction in the budget. Is that just for budget constraint reasons?

Dr. TRIVELPIECE. Well, we have been trying to constrain the budget also in recognition of the deficits that are facing us, and so we have not started new projects or built new mortgages. We are merely trying to carry out those elements of the program that we believe make it a balanced program, and in some cases we have stretched out some items in time in order to help control the budget and in other cases there have been parts of the fusion program that have been terminated in the present budget climate.

Senator FORD. This doesn't go back to the recognition of the present energy or world energy situation?

Dr. TRIVELPIECE. No.

Senator FORD. It is just a budget constraint?

Dr. TRIVELPIECE. We are trying to maintain a balanced program which we think will provide the United States with the appropriate answers in fusion at some time in the future.

Senator FORD. Mr. Chairman, I thank you for your courtesy.

Senator DOMENICI. Well, in that regard, Doctor, I note that your budget assumes that we will not go forward with the Torus fusion device at Oak Ridge.

I wonder if I understand correctly that on reevaluation this element of advanced concept program appears to be somewhat less advanced than we thought. Is that one of the reasons that it is being eliminated?

Dr. TRIVELPIECE. It is a combination of situations. Certainly the budgetary issues are one of the driving factors. The other driving factor has been the technical evaluation. I think that under other circumstances we might well be pushing forward with it in order to get the information that can be gained with respect to what high-power microwaves do to magnetically confined plasma. That would be an important technical piece of information to have, but the cost of the overall project in the present budget circumstances combined with technical evaluation make it difficult to responsibly be proposing to go forward with it.

Senator DOMENICI. Your university research support is somewhat up, as I indicated in my opening remarks, from what was appropriated, and I have already in my opening remarks indicated my support for your doing that, and the math and science, your initiative is about $6 million I think to upgrade university research equipment, and you commented on that in your summary remarks.

However, there is a decrease if I understand the proposed budget correctly in the university/national laboratory cooperative research program. How do you explain cutting back that and increasing the other?

Dr. TRIVELPIECE. The laboratory cooperative program is funded at a constant level of effort. In constant dollars, however, it has been decreasing a little bit by inflation.

Senator DOMENICI. So you are continuing that university/national laboratory co-op? It is just not going up?

Dr. TRIVELPIECE. Yes, sir.

Senator DOMENICI. Is that what you are saying?

Dr. TRIVELPIECE. Yes.

Senator DOMENICI. So to the extent it is not going up as high as inflation, it is somewhat restrained in the budget? Is that a fair statement?

Dr. TRIVELPIECE. Yes, sir.

Senator DOMENICI. Senator Melcher, do you have any further questions?

Senator MELCHER. No, I don't. Thank you, Mr. Chairman, and thank you, Doctor.

Senator DOMENICI. Doctor, I am most appreciative of your accommodating us today, and obviously you have given us a lot more detail in your complete testimony.

If we have any specific questions with reference to it or if any other members do, we will submit them to you in the next few days for your response in the record.

Unless you have something further to add, we stand adjourned.

Dr. **TRIVELPIECE**. Thank you very much.

[Whereupon, at 10:30 a.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX I

ANSWERS TO ADDITIONAL QUESTIONS SUBMITTED FOR THE RECORD FROM DR. TRIVELPIECE

Department of Energy
Washington, D.C. 20585

April 11, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy and Natural Resources
Washington, D.C. 20510

Dear Mr. Chairman:

Following the February 28, 1983, hearing before the Energy and Natural Resources Subcommittee on Energy Research and Development, you submitted questions to Dr. Alvin W. Trivelpiece for response. Answers to those questions are enclosed.

A copy of the answers has been sent to Mr. Astrin of the Committee staff.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bc: Mr. Al Astrin
Committee Staff

QUESTIONS FROM SENATOR PETE V. DOMENICI

Dr. Trivelpiece, in your testimony before the Subcommittee we discussed the ability of the Department to screen companies making inquiries with regard to technology transfer. You pointed out that the open literature was available to anyone seeking to receive that information from the Technical Information Center at Oak Ridge. I am more interested in those somewhat informal contacts made between researchers at national laboratories and inquiring employees of private corporations. What guidelines has the Department laid down for the professionals at our national laboratories with regard to the transfer of unpublished data?

There are informal contacts between researchers at the national laboratories and inquiring employees of private corporations in regard to technology transfer. For example, we are implementing the Stevenson-Wydler Technology Innovation Act of 1980 which requires each laboratory to have an Office of Research and Technology Applications, ORTA, or equivalent function. One of the ORTA functions is to identify technology with potential commercial application. The key to our approach is the personal interactions of the laboratory researchers themselves with potential public and private users of the technology. In this way, work in progress may be communicated which has not yet reached published form, with the exception of constraints caused by classification or plans for future patent application or publication by the researcher.

Our program builds on a long history of transfers dating all the way back to the early days of the Atomic Energy Commission; however, technology transfer is not a simple or easy thing to achieve. Therefore, our program is also addressing: identification of barriers to technology transfer, and recommendation of policies to facilitate transfer of technology. The Department has issued class patent waivers to outside users of the laboratories and facilities.

2. While the Department is not requesting funds for construction related to the EBT-P, you are requesting funds for experimental work with EBT-S. What are the nature of the problems that will be investigated with the EBT-S and how will they relate to answering the questions that have led the Department to the cancellation of the EBT-P?

An EBT Program Review was held in February 1983. The review panel recommended that the EBT program give top priority over the next 12 to 18 months to improving our understanding of the performance of the EBT-S. Experiments will be done to resolve the critical physics questions of whether or not transport in EBT-S is consistent with neoclassical theory. The results of these experiments will be obtained by the use of improved diagnostics and split magnetic coils. These experiments will improve our understanding of the EBT-S performance. The results will also reduce the technical risk associated with the EBT proof-of-principle experiment. Experiments are also being considered to improve EBT-S performance based on new ideas for the bumpy torus reactor concept.

Is it appropriate to cease all work on the EBT-P while experimental work is still being undertaken on EBT-S related to the uncertainties on EBT-P? Should some funds be provided for the EBT-P relating to the modification of design of that machine based upon the findings of the experimental work on the EBT-S?

Future steps in the EBT program will be decided on the basis of the outcome of this effort on EBT-S. The present EBT proof-of-principle device (EBT-P) was designed in 1977. Since that time the state of knowledge of EBT's has changed. We expect even more changes over the next 12 to 18 months. If warranted at that time, consideration will be given to a new proof-of-principle device.

3. Has the Department of Energy sought guidance from the electric utility industry as to what specifications for a fusion reactor would be necessary to make that reactor an economically competitive electrical energy producer?

The utility industry in the United States has a great diversity of opinion among its various constituents about the best technologies to generate electricity for its customers. Many factors influence the approach that a utility company considers when selecting the methods to be used for electricity generation. It is this great diversity of thought and requirements which inhibits the utility industry from settling upon specific criteria for future fusion power reactors. However, the general criteria are quite clear. The most obvious is that the cost of electricity generated by fusion power plants must be competitive with the cost of electricity generated by other means used by the utility.

Please provide the Subcommittee with any relevant documents in this regard and summarize their findings for the record. Please provide a table summarizing the elements of the Department's two main line fusion reactor programs and the advanced concepts program as they relate to the "specifications" called for by the electric utility industry.

Despite the utility industry's inability to settle upon specific criteria for future fusion power reactors as I mentioned earlier, the Department of Energy has sought guidance from the electric utility industry in the past in several ways and will continue to seek such guidance in the future. One way this guidance is provided to DOE is through our involvement with the Electric Power Research Institute, EPRI, which is an organization funded by the utility industry to conduct research into various aspects of electricity generation. EPRI also conducts research in the fusion area and many official contacts between DOE and EPRI assure complimentary programs directed at questions of importance to utilities. In addition, the fusion reactor design studies program includes input from utilities on every major design effort. For example, during the design of a commercial-sized tokamak named STARFIRE, a Utility Advisory Committee was established which was directly involved in the decision-making process as the design evolved to assure that the STARFIRE design was attractive to utilities. The group provided a representative cross-section of utilities in terms of geographic location, size, climatic conditions, fuel mix, population density, customer mix and sociopolitical environment. The impact of this advisory committee on the design is described in the appendix of the STARFIRE report. Another example of utility involvement in providing specifications and criteria for fusion power reactors is the design of a tandem mirror commercial-sized reactor, the Mirror Advanced Reactor Study, MARS, which is currently underway. In this case, a utility company is actually a part of the design team. In addition, a presentation of the current status of the MARS design was made to a group of utility executives whose comments resulted in several changes to the MARS design.

4. Please provide a table summarizing the operational time available to each of the major high energy physics and nuclear physics experimental facilities provided for in the FY 82 and FY 83 budgets and the President's request for FY 84. Please explain any major deviations in operational time for a given machine over that three-year budget period.

I will provide this information for the record.

NUCLEAR PHYSICS
ACCELERATOR FACILITY OPERATIONS
BEAM HOURS FOR RESEARCH

	Actual FY 1982	Estimate FY 1983	Estimate Based On Budget Request FY 1984
Clinton P. Anderson Meson Physics Facility	3095	3100	3000
LBL Bevalac	1829	2600	3500
William H. Bates Linear Accelerator Facility	1632	3000	3300
Holifield Heavy Ion Research Facility	1611	4400	4500
LBL 88-Inch Cyclotron	3523	3500	3500
Argonne Tandem/Linac	3077	2500	3000
BNL Double MP Tandem	5164	4560	4500

"Beam Hours for Research" is the total hours the facility is in operation for the purpose of actually delivering beam for research use. This excludes time for tuning, machine studies, unscheduled maintenance, and scheduled shutdowns.

For three- to six-month portions of FY 1982, Bevalac, Bates, and Holifield were each shut down for completion of construction projects at those facilities. The reductions in FY 1983 beam hours with respect to FY 1982 beam hours for the Argonne Tandem/Linac and BNL Double MP Tandem are due to FY 1983 budgetary constraints in the Heavy Ion Nuclear Physics subprogram.

HIGH ENERGY PHYSICS
ACCELERATOR FACILITY UTILIZATION

	Actual FY 1982	Estimate FY 1983[1]	Estimate Based On Budget Request FY 1984
Brookhaven National Laboratory Utilization (Weeks)	20	30	30
Fermi National Accelerator Laboratory Utilization (Weeks)	21	36[2]	36
Stanford Linear Accelerator Center Utilization (Weeks)			
a. Pulse Rate, Linac (%)[3]	19%	26%	25%
b. Weeks of Operation	32	36	36

[1] Based on DOE/OMB interpretation of distribution of resources under the FY 1983 Continuing Resolution. This represents a major effort to improve the utilization of facilities above the low levels of FY 1982.

[2] FY 1983 is the year of commissioning and possible initial operation for the superconducting Energy Saver accelerator with the existing conventional accelerator being operated at 150 GeV as an injector into the Energy Saver. FY 1984 is expected to include full operation of the Energy Saver and the initiation of the early phase Tevatron II 1000 GeV program at Fermilab, opening exciting and unique new research opportunities.

[3] Pulse rate is a major factor for fixed-target experiments only. Utilization of the Stanford Linear Accelerator Center's SPEAR and PEP electron-positron colliders is determined by the number of weeks of operation.

5.

In your statement you say that the rate of carbon dioxide emissions in the atmosphere has declined from approximately 4.6% to 1.9%. Please provide the Subcommittee with the source of this estimate.

The estimate comes from a report entitled "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950 - 1981," a copy of which will be provided to the Subcommittee as soon as they are published. We expect them to be ready in the next month. At that time if you would take particular note of Fig. E-1, pg. 4.

QUESTIONS FROM JAMES A. McCLURE

1. On page 8 of your testimony you state, "There have been many spinoffs including the technology of superconducting materials and devices, radio frequency power generation, materials analysis, and medical applications including methods of treating cancer." Do you have any estimates of the impact on GNP that the research results of high energy and nuclear physics produce? Do you have estimates or examples of how long breakthroughs or developments in high energy and nuclear physics take to make their way into the economy as reflected in new business product lines or improved ways of doing business?

High Energy and Nuclear Physics are forefront fields of very basic research at the frontier of knowledge. Their goal is to achieve detailed, quantitative knowledge of the fundamental structure and properties of matter and energy and an understanding of the basic forces in nature. The knowledge, instruments and applications that have resulted from research in these highly technological basic research areas pervade modern American society. They serve as the basis for much of our national defense strategy, for therapeutic and diagnostic medical applications, for generation of electricity with nuclear processes and for a diverse array of applications in industry and other areas of science.

It is very difficult to estimate the impact of applications on GNP because the impact is diffuse - affecting not only the efficiency of producing goods, but also the ability to produce better goods, to avoid adverse environmental impact and to provide the means to relieve human suffering.

Regarding the examples you have just mentioned, superconducting materials have significant potential for applications in electric power transmission and in transportation via superconducting motors, for example in naval ships, and via superconducting magnets for such applications as levitated trains. Radio frequency power sources have had an inmeasurable effect on Defense applications. Methods of materials analysis with particle beams and with isotopes produced by accelerators are common in research and industry. Methods of medical diagnosis and therapy using X-rays. isotopes and electron beams have become standard practice. On the average, a nuclear medicine procedure is performed on one out of every two people admitted in hospitals in the U.S. Such applications are rooted in the "ancient history" of research in high energy and nuclear physics. More recently, thousands of patients have been treated for cancer with neutrons, pions and other heavy accelerated particle beams in clinical trials. The processing of material to change its properties by radiation is a good quantitative example of the impact on industry. At the present time there are more than 300 electron accelerators in industrial processing plants with an aggregate beam capacity approaching 15 megawatts. New electron beam facilities are being installed at the rate of 30 to 40 per year. The market value of all the irradiated products produced by these facilities exceeds $2 billion annually and is growing at about 20% per year. In addition, ion implantation using small accelerators to produce semiconductor devices is a multi-billion dollar industry.

The time it takes from a new breakthrough in knowledge to practical application is widely variable, ranging from less than a year to decades. In fields such as high energy and nuclear physics, which require the most advanced technology developments, some spinoffs from technology developments are applied quickly; applications of more fundamental discoveries usually occur slowly. The variability of the time span from discovery to application and the uncertainty of the place of application also makes calculation of a dollar value impact on any segment of the economy or GNP very difficult.

2. What has been the impact of the recession that we have been experiencing for the last several years on investment in high energy and nuclear physics in OECD countries - do we have any comparable data for the Soviet bloc?

Overall, the activity in high energy and nuclear physics in OECD countries has been considered important to progress in science and technology as it impacts upon new high technology industry and economic development in general. The research level has been maintained in European OECD countries and even increased.

In high energy physics a major new initiative is underway at the European Organization for Nuclear Research, CERN, to provide a very high energy electron-positron colliding beam facility called the Large Electron Positron Project, LEP, which provides 50 Gev x 50 Gev in the approved Phase I. West Germany has recently announced plans to proceed with the Hadron-Elektron-Ring-Anlage, HERA, facility to provide 30 Gev x 800 Gev electron-proton collisions. These two construction projects, together with the associated detector and personnel costs, represent an investment of about $2 billion. In the case of non-European members of OECD, the increase in Japan has been dramatic in conjunction with their TRISTAN electron-positron colliding beam construction project at Tsukuaba-gun, the Japanese "Science City".

In nuclear physics, major upgrades and new construction of many Western European facilities are in progress, including electron accelerators at the National Institute for Nuclear and High Energy Physics, Amsterdam, Netherlands and the 175 MeV continuous beam racetrack microtron at the University of Mainz, Mainz, West Germany; the high energy, heavy ion facility at the Institute for Heavy Ion Research, Darmstadt, West Germany; the twin cyclotron heavy ion facility at the Grand Accelerator National d'Ions Lourds in Caen, France; the superconducting cyclotron laboratory at Milan, Italy; the 30 million volt electrostatic accelerator at Daresbury, England; the Swiss meson factory, Swiss Institute for Nuclear Research, Zurich, Switzerland; the light ion accelerator at Saclay, Saturne; and the low energy antiproton ring, LEAR, at CERN. The Japanese have just brought into research use an electron stretcher ring at Tohoku and a 20 million volt electrostatic accelerator at the Japan Atomic Energy Research Institute in Tokai, and are upgrading kaon beam capability at the Japanese National Laboratory for High Energy Physics, KEK.

There is little specific data for Soviet bloc countries, however, activities in high energy and nuclear physics appear to be well maintained in the U.S.S.R. with work proceeding on a major 3 TEV fixed target proton accelerator construction effort at Serpukhov.

3. On page 13 of your testimony you state, "As an ancillary benefit, pursuit of Nuclear Physics program goals provides a national base of knowledge, techniques, instrumentation, and skilled manpower in critical technologies." Please provide examples of the critical technologies for which the nuclear physics program provides manpower.

The DOE Nuclear Physics program provides over 80% of the total Federal support of basic nuclear research in the United States. It is through basic nuclear research that young scientists receive training at the graduate student and postdoctoral levels. Also, especially at the national laboratories, basic nuclear research scientists work closely with applied nuclear scientists and often collaborate with applied nuclear scientists on projects of mutual interest. As national needs and opportunities arise in applied areas, these basic nuclear research scientists easily and frequently transfer into applied technology projects. The Department of Energy and National Science Foundation's Nuclear Science Advisory Committee studies conclude that one-third to one-half of nuclear scientists who received their training in basic research are now employed in applied research.

Examples of critical technologies for which the Nuclear Physics program provides manpower include: nuclear radiation detection and analysis; particle accelerator design and development; particle accelerator control and monitoring systems; design and development of nuclear reactor components; management of nuclear waste products; handling and monitoring of nuclear materials; design and development of nuclear weapons systems; production and use of radioisotopes; application of nuclear radiation in cancer therapy; and computer hardware and software for rapid, efficient manipulation and analysis of large quantities of data.

4. On page 15 of your testimony in a discussion on the value of heavy ion research you state, "From these experiments, we expect to learn how nuclear matter acts as it is compressed and how energy moves through nuclear matter." What will the applicability be of the research results to the work currently being performed in inertial confinement fusion?

In the collision of nuclei at high energy, very large amounts of energy, mass, linear momentum, and angular momentum can be exchanged between the colliding partners. In those collisions in which the nuclei attempt to interpenetrate each other, nuclear matter is compressed to densities otherwise found only in the interior of stars and experiences high concentrations of energy. The neutrons and protons inside the colliding nuclei overlap each other. We have very preliminary evidence that the quarks bound inside these neutrons and protons form entirely new structures and combinations. Investigation of the behavior of nuclear matter under conditions of extreme stress, such as found in high energy collisions, is now a very important frontier of basic nuclear research.

Presently known applicability of high energy, heavy ion nuclear research experiments to inertial confinement fusion lies in the development of particle accelerator technology, beam transport systems, and radiation detection systems which are common features of both heavy ion nuclear physics and inertial confinement fusion work. As an outstanding example of this synergism, we note that scientists and engineers in Lawrence Berkeley Laboratory's Accelerator and Fusion Research Division are responsible both for Bevalac operations and improvements and for a key portion of the DOE inertial confinement fusion program.

5. On page 18 of your testimony you state in part, "Even more important is the need for basic scientific research unconstrained by preconceived notions of which technologies will be important in the future." Further on you state, "Often it is only in retrospect that the true importance of research results can be assessed." Given these statements, how do you set your priorities as to which research projects you will fund and at what point funding should be terminated because the project is heading up a "blind alley".

Basic Energy Sciences makes extensive use of workshops and study panels comprised of the nation's leading scientists to analyze subfields of science to identify opportunities for research. This information coupled with knowledge of research needs and anticipated future directions of energy technologies is used at the subprogram level as a guide for selection of research proposals for funding after they have been peer reviewed. A project proposed for funding is then reviewed internally to ensure maintenance of standards of excellence and appropriateness for support by the DOE.

Most projects have well defined objectives toward which progress can be measured. When these objectives are met or the project productivity fails, support is brought to a close. If there is a question in the project monitors mind the project is subjected to a peer review to determine whether support should be continued or terminated. The average life of a project is 6 to 7 years.

6. On page 20 of your testimony you discuss several of the accomplishments of the nuclear sciences program as it relates to nuclear energy. One of these accomplishments appears to suggest that it might be possible at some point in the future to reprocess nuclear fuel using techniques similar to those used in laser-based uranium enrichment processes. Have you specifically considered this possibility and its feasibility? If not, would you please do so.

No, we have not because the research only examined certain aspects of laser isotope separation. The extension to fuel reprocessing is an intriguing concept and we will work with the waste management program staff to examine it further.

You also indicate new research on the "binding of actinides to naturally occurring organic materials and that migration of plutonium through soils rich in these materials would be very slow." What findings have you made on the binding of transuranic wastes, such as those found in the Defense Programs, to materials occurring in soils, since the mid-1970's? Can you summarize these for me?

Our research in this area has principally addressed the fundamental solution chemistry of certain actinides under conditions that approximate the environment to determine the probable nature of the migrating species. These migrating species are chemically complex and bind in varying degrees to different soil materials. In brief, it is clear that the actinides found in transuranic wastes form strong complexes with environmental species, principally carbonate, bicarbonate, and humate; and that as a result of this, the mobility of the actinides is significantly retarded.

7. On page 21 of your testimony you refer to an "applied math effort involving automated reasoning that provides a solution to the problem of showing that single component failures could not inhibit the shutdown of a nuclear reactor." Is the Nuclear Regulatory Commission accepting your model and are they using it currently in nuclear plant licensing proceedings?

The demonstration of the application of automated reasoning techniques to reactor safety systems was carried out on a simple experimental reactor (TREAT). The complexity of handling the needed data for operational reactor power plants will be much greater. Current work continues at Argonne National Laboratory on problem decomposition into simpler modular systems and, in conjunction with workers at Idaho Falls, on operator alert systems. It is projected that within five years, reactor analysis systems based on automated reasoning techniques could be seriously considered for adoption by the Nuclear Regulatory Commission and brought into production use.

On page 21 of your testimony you refer to a geosciences effort that analysed the Columbia River basalts. Have you performed similar studies of other sites where Defense Programs currently stores its wastes? Please identify for me those sites that you have specifically analysed the chemical properties of the soils and their ability to retain long-lived transuranic elements found in Defense Program waste.

No, similar studies have not been performed in the Geosciences program on materials from other sites where Defense Programs currently store wastes. The experiments carried out under the Basic Energy Sciences program are generic in nature. They are typically designed to provide very detailed geochemical or geophysical analysis to characterize the physico-chemical properties which apply, in a broad sense, to rocks and soils. The Columbia River Basalt used in the experiment is representative of 'basalt' as a rock, rather than basalt at a site. The result indicates that it is the presence of iron in the divalent state that is significant in immobilizing neptunium; and this result applies not only to basalt, but all rock or soil that may be associated with repositories or backfill. The new insight will help in designing and interpreting tests specific to various storage sites.

On page 21 of your testimony you suggest the scientific feasibility of producing a storage battery with electrodes made of light polyacetylene sheets rather than lead. Please identify your schedule for the demonstration of this concept and the funding levels specifically required to support the schedule.

Our Office of Basic Energy Sciences, through its Division of Advanced Energy Projects, has been supporting exploratory research on the concept of polyacetylene batteries since March 1, 1981. The bulk of the work is performed at the University of Pennsylvania under the direction of Professor Alan G. MacDiarmid, one of the co-inventors of the concept. The other co-inventor, Professor Alan J. Heeger has since moved from the University of Pennsylvania to the University of California at Santa Barbara, and continues to receive our support through that institution.

The most important aspect of the concept is that it uses, for the first time, the newly established fact that certain organic polymers can act as good storage media for electrical energy and that the stored charge can be delivered on demand at a high rate of power.

The Division of Advanced Energy Projects supports exploratory research on novel concepts, such as the polyacetylene battery, for a limited time only, usually not exceeding three years. It is expected that ideas worth further development will subsequently find support from the technology programs of this Department, from other Federal agencies or, preferably, from industry. I am pleased to report that, in the case of polyacetylene batteries, a considerable development effort is already underway in industry. Specifically, the University of Pennsylvania's patents on the electrochemistry of conducting polymers and its application in the fabrication of rechargeable batteries have been licensed to Allied Corporation and its subsidiary, C&D Company, for North America and Japan; Allied is presently conducting an intensive inhouse effort aimed at development of polymer batteries. BASF Company, the largest chemical company in Europe, has the license for Europe. A recent announcement shows that BASF Company and VARTA Battery Company, the second largest battery company in the world, have combined forces on the development of polymer batteries. Extensive work on the commercial development of such batteries is also being carried out in Japan.

Even though work towards commercial development of polymer batteries is evidently under way, additional basic studies of the concept are required, as very significant improvements in the already demonstrated, and impressive, performance characteristics are possible. To date Advanced Energy Projects has provided over $600,000 in support of a three year research effort on this concept. We are committed to see to it that such basic studies continue to receive needed funding.

8. On page 24 of your testimony you discuss the construction of the "National Center for Advanced Materials." What was the basis for the Department deciding to site this new initiative at LBL?

The decision to establish the Center at Lawrence Berkeley Laboratory is based on many considerations. Some of them come from the recommendations made by the Energy Research Advisory Board's Laboratory Review Panel. These recommendations suggested that the Department should seek to redirect its laboratories into new and scientifically more productive activities, that it use its laboratories in ways that support the Nation's higher education enterprise, that it seek to get them more involved with industry in ways that help improve the U.S. industrial science and technology base, and finally, that it not regard its laboratories simply as sites at which various unrelated technical projects are performed by the different departmental elements, but rather it should regard the laboratories to the extent possible as institutions and treat them accordingly.

Each major multiprogram laboratory annually submits an institutional plan to the Department. In this plan, the laboratory is requested to identify its long range plans with reepect to ongoing activities as well as any new activities that it believes might make better use of existing facilities and skills to work on problems associated with the Department's missions. In its 1983 plan, the Lawrence Berkeley Laboratory proposed to establish a National Center for Advanced Materials. The initial plan was modified through discussions with DOE program managers and the budget initiative was developed.

The Lawrence Berkeley Laboratory has an existing long term basic research program in advanced materials. This existing program includes research on metals and alloys, ceramics, catalysts, preparation and characterization of materials and a small but excellent program on the science of surfaces. In addition LBL has developed a National Center for Electron Microscopy where unique electron microscopes are used in the study of the behavior of materials. This research program is conducted primarily by tenured professors of the University of California and over 200 graduate students. These resources of trained scientists, students, equipment and facilities provide the base for developing a new center.

Please provide the funding levels in the Advanced Materials Area that has been provided to LBL for the previous 5 years.

The LBL budgets for advanced materials research the last five years are:

In Millions

	79	80	81	82	83
Total	$6.10	$7.00	$7.51	$8.12	$8.89

Please also identify any unique capability that would be required to support such an initiative.

The unique capabilities that would be required to support such an initiative include: a highly respected research institution that would be able to attract new staff, a resident respected advanced materials research program with unique facilities to serve as the foundation for the initiative, an institution contiguous to or part of a large university with strong science and engineering departments and a large student body to be attracted into advance research and training in the field of advanced materials research, a resident experienced staff of accelerator designers, builders and operators to build the Advanced Light Source, a staff experienced in research using synchrotron radiation, a geographic location with a high concentration of high technology industries, an institution with a breadth of services and management capability to ensure success of initiative, and finally a laboratory with strong leadership capable of or in need of being directed into a new major mission area.

Please identify other potential sites that you considered and rejected for the siting of the National Center for Advanced Materials.

There were no other proposals submitted for consideration.

9. On page 29 of your testimony in describing the objective of the human health research subprogram you state that you "determine whether exposure of humans to agents associated with Atomic Energy Defense activities and energy production and use results in such health effects as cancer and genetic defects." Please discuss qualitatively and quantitatively the increase in our understanding since the mid-1970's of the health effects of transuranic elements found in Defense Program waste. Please characterize the level of knowledge in 1975. Identify the principle unknowns at that time and discuss major research finds since 1975 and discuss today's level of understanding and the uncertainty associated with it.

Included in defense-related wastes are the transuranic elements neptunium, plutonium, americium, curium, californium, berkelium, and einsteinium. The toxicity of these radioelements has been a major concern ever since they were first produced in significant quantities in the early 1940s. During the past 40 years, many experiments were performed to define their chemical properties, modes of transport in the environment, metabolic behavior in animals and man, and potential health effects.

As early as 1951, sufficient biological information had accumulated to permit the International Commission on Radiological Protection, ICRP, to establish a maximum permissible human body burden for transuranic elements of 0.04 microcuries, corresponding to an animal bone dose of 15 rems, the forerunner of current protection standards for radiation workers. By the mid-1970s, useful but incomplete information had been acquired concerning the metabolism and radiation dosimetry of inhaled and ingested transuranic elements. By use of data from urine assays, it was possible to make crude estimates of body burdens of certain transuranic elements in exposed individuals. At this time, also, attention had begun to focus on the importance of microdosimetry which is radiation dose distribution within tissues on a microscopic scale. For example, several scientists had postulated that, when lung tissue is nonuniformly irradiated by microscopic particles of insoluble plutonium-239 dioxide, PuO_2, the risk of tumor induction might be as much as 100,000 times greater than that calculated on the basis of data from animals in which the lung was exposed to an equivalent but uniformly distributed radiation dose. In the mid-1970s, this so-called "hot particle" problem was unresolved.

Of the transuranium elements, plutonium has received the greatest attention from biologists. In a review article published in 1974, Science, 183, 715-722, the authors concluded that more was known about the toxicology of plutonium than about most hazardous elements. From studies of experimental animals, we knew then that ingested plutonium was extremely poorly absorbed from the gastrointestinal tract in adult mammals, a fraction of less than one-hundredth of one percent, that if inhaled it could be retained in the lung for long periods of time, and that when absorbed from the lung or gastrointestinal tract it would deposit principally in the skeleton and the liver, remaining there for the life of the animal. It was known, too, that plutonium could cause cancers in lung and bone of experimental animals, and the approximate relationship between radiation dose and cancer incidence at high dose levels had been established.

What we did not have in 1975, was any great confidence in how to apply the accumulated experimental data on the transuranic elements to man. During the past 10 years, we have greatly expanded our data base. We now have more data on different chemical forms of plutonium, administered by various routes such as inhalation, injection, ingestion at more and lower dose levels, and in more animal species. These data allow us to be much more certain of our observations and their implications for man. Analogous, but less extensive progress has been made in animal research on the biological properties of other transuranic elements. The newer data demonstrate that there are important differences in the manner in which different transuranic elements are handled by the animal body. For example, inhaled plutonium-239 dioxide is avidly retained in lung tissue and mainly gives rise to lung tumors. By contrast, it has been found that the corresponding oxides of plutonium-238, americium-241, and curium-244, unlike plutonium-239, undergo significant translocation from lung to bone and therefore may produce bone-related tumors. In addition, analysis of more recent animal experiments, primarily at three Department of Energy laboratories, has clearly established that small particles, "hot particles," of plutonium deposited in lung tissue or the liver are not significantly more hazardous than uniformly distributed radionuclides which produce an equivalent total radiation dose.

Human post-mortem data obtained in the past 10 years, have taught us much about the distribution of plutonium; from fallout, accidents, and occupational exposures, in man. Data on the metabolism and fate of other actinides has been obtained from studies in which humans have been accidentally exposed. With advanced instrumental techniques, it is now possible to determine human body burdens of plutonium and other actinide elements more accurately by directly measuring their radiation emissions. We have learned from these sources of information that previous methods of estimating actinide body burdens from urine-assay data were inadequate.

The general agreement between the accumulated human data and the more extensive animal data increases our confidence in the extrapolation of animal data to man. We still have no direct information on effects of plutonium or other transuranic elements in man, but intensive study of several groups of occupationally exposed workers has placed upper limits on the incidence of effects that one can expect to see in man and serves to strengthen the correlation with animal data.

Other specific areas in which progress has been made in the past 10 years include the following: development of improved capabilities for the safe and effective removal of plutonium, americium, and other actinides from human tissues through the use of the chelating agent zinc-DTPA, diethylenetriaminepentaacetic acid; demonstration that exposure to cigarette smoke may increase retention of plutonium in the respiratory tract of rats, but by no more than a factor of two; demonstration that plutonium, at the very low concentrations and in the chemical forms apt to be encountered in the environment, may be absorbed from the gastrointestinal tract at a rate which is 10 to 30 times greater than previously assumed; and that absorption by newborn rodents may be 100 times greater than by the adult--in view of the extremely low absorption in the adult animal, however, the resulting higher absorptions is still so low as to be unimportant from a practical point of view; demonstration that plutonium in very young or in old animals shows no greatly different behavior, or toxicity, than in the young adult animals more commonly studied; accumulation of comparative animal toxicity data, which will soon allow us to compare transuranics with radium and other radionuclides for which human toxicity data are available; accumulation of extensive data on the transport of plutonium through environmental pathways, by which it might reach man. Such data are essential to the establishment of realistic environmental standards and for the evaluation of accident consequences.

Continuing research efforts are focused on: learning if there are any synergistic interactions between transuranium radionuclides and other toxic agents, for example, cigarette smoke, industrial chemicals, etc., that might produce unexpected health risks; studying the risks from special chemical forms of transuranic radionuclides that are likely to be encountered by people in future nuclear-related industries; determining the cancer risks from exposures to very low levels of radiation such as less than 10 rads by using carefully designed studies in laboratory animals; studying the potential health risks, if any, which are observable in people who work with transuranium elements; and developing methods and chemical compounds to reduce body burdens of transuranics after accidental intakes.

10. **On page 33 and 34 of your testimony you discuss the environmental research subprogram and indicate that one of its objectives is "determine effects of defense and energy activities on critical ecosystems and the resiliency of these systems to continued stress." Please identify those specific Defense Program sites and/or national laboratories that have been part of the assessment base of your program.**

The Defense Program sites and/or national laboratories that are a part of our environmental research program concern almost all of the lands and laboratories presently under the DOE stewardship. Major research programs are being carried out at the Savannah River Plant in South Carolina, Oak Ridge National Laboratory in Tennessee, the Nevada Test Site in Nevada, the Idaho National Engineering Laboratory in Idaho, the Los Alamos National Laboratory in New Mexico, and the Hanford Reservation in Washington. To a much lesser degree other sites such as Rocky Flats in Colorado have been used for research.

The concept of utilizing these lands for research has been detailed and printed following Hearings on the Environmental Research Reserve Networks before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, Ninety-Fifth Congress, first session July 28, 29, 1977, No. 23, U.S. Government Printing Office, Washington, D.C., 1977.

Lands obtained by DOE's predecessor, the Atomic Energy Commission, were, for security reasons, relatively large isolated and protected tracts. Fortuitously these lands are representative of the major ecosystems of the United States. Of particular benefit to the ecological research activities of DOE, these reservations have natural areas which can be used as control sites for evaluating a full range of environmental questions associated with defense/energy development--nuclear and fossil fuel power plants, heated ponds and streams, grazed lands, power transmission lines, land altered by construction activities, etc.

11. In your budget submittal you discuss the recent accomplishments of the carbon dioxide research subprogram. You note a change in the rate of carbon dioxide emissions from 4.6% to 1.9% has been detected. Please elaborate on this comment and discuss what you believe the implications of this change are.

The growth rate of CO_2 emissions from fossil fuel burning has decreased since 1973. In other words, although more CO_2 is produced each year than the previous one, the annual increases are smaller now than they used to be. For example, the annual rate of increase in CO_2 emissions from oil declined from 7.1%-pre 1973 to 1.0%-post 1973, and significant decreases occurred in the growth rates of emissions from coal and gas as well. This decrease is clearly related to dramatic increases in energy prices beginning in 1973. More CO_2 is generated when energy is cheap; less when costs rise. We are lucky that this has happened. Time is now available to collect data and improve models so that we may develop the scientific knowledge base on atmospheric carbon dioxide effects to aid in policy decision making.

An implication of the reduced growth rate of CO_2 emissions is a slower build-up of atmospheric CO_2. If the current low rate of increase continues, the time before CO_2-related effects are noticeable would be extended. At the lower growth rate of CO_2 emissions, the time when atmospheric CO_2 will increase to 600 parts per million, almost double the present level, is now calculated to be closer to the year 2075 than the year 2025. The earlier time was based on the higher growth rates of 4 to 5%.

12. Please describe the role that the advanced fusion concepts program plays in supporting the two mainline concepts, i.e., the tokamak and the tandem mirror. Also discuss the criteria that you use to determine those concepts worthy of support.

The advanced fusion concepts program currently includes research on four confinement concepts: Elmo Bumpy Torus (EBT), Stellarator/Torsatron, Reversed Field Pinch, and Compact Toroids. Additional research in this general area includes advanced fuel cycles and exploration of advanced confinement ideas. The advanced fusion concepts program plays two key roles in supporting the mainline concepts. The first role is to help complete our overall understanding of the physics and technology data base for magnetic fusion. Fusion physics and technology is sufficiently complex that too narrow a focus may prevent us from discovering important ingredients. The advanced fusion concepts provide the perspective from which these ingredients may be better perceived. For example, the benefits of hot electrons and the development of gyrotrons initially came from EBT research. Both of these are now being applied in the mirror and tokamak program.

The second role is to provide stimulation and competition to the mainline concepts which lead to improvements in these concepts. For example, the attractiveness of the steady state EBT and stellarator reactors spurred the tokamak community to develop the possibility of a steady state tokamak.

The advanced fusion concepts program plays a third important role, to develop potentially improved reactor concepts which may be the reactor choice of the future. For example, the reversed field pinch and the compact toroid concepts might allow development of small, high power density reactors with lower capital cost than the mainline concepts. Of course, many years of research will be required to determine whether this is in fact possible.

There are several criteria used to determine concepts worthy of support. However, the data base on advanced concepts, especially exploratory ones, is usually so meager that the criteria cannot be applied in a rote fashion. The criteria must be supplemented by sound technical judgment, and the specifics of each concept taken into account. They include the possibility of extrapolating to a reactor; novel ideas or ingredients which might result in a qualitatively improved reactor; relationship to established fusion concepts to allow for cross-fertilization and support of the mainlines, as well as the equally important background support to the alternate from the mainlines; credibility of the physics basis for the concept; and funding levels and timescales required to verify the correctness of the physics basis.

13.

Provide your reasons for terminating your effort on the Elmo Bumpy Torus proof-of-principle project at the Oak Ridge National Laboratory.

The Department has decided to bring present design activities on the Elmo Bumpy Torus Proof-of-Principle project to an orderly stop rather than initiate construction on this major project at this time. The program has deferred efforts on EBTP. This action is consistent with the present technical and budgetary circumstances. Recent physics research results have revealed certain uncertainties in the fundamental scaling assumptions. Based on this, it was decided it was not prudent to proceed with construction of this facility at this time. Instead, we intend to conduct further investigations with existing facilities to clarify these underlying issues.

14. On page 50 of your testimony you state, "If international cooperation were to become so extensive (in the fusion program) as to result in programmatic dependencies, a careful assessment of the consequences of this interdependence would be undertaken." Given this statement, what do you believe the possibility is for international cooperation on a project like FMIT given the highly unique and important research data that it is likely to produce.

We believe that the outlook for multinational collaboration in the construction and operation of the FMIT project is favorable.

Discussions directed toward such an agreement are proceeding under the auspices of the International Energy Agency, and international review of the programmatic basis for and technical status of the FMIT project has been favorable. This international assessment is not yet complete but it does recognize the unique technological qualities and the necessity of the FMIT as a critical element in the mix of irradiation facilities necessary for fusion materials research. We anticipate that preliminary judgments by Japan, the European Community and Canada to join with us in construction and operation of the FMIT might be established during the summer of 1983. Affirmative decisions at that point in time and associated budget cycles are consistent with initiation of construction in 1985.

15. At what point in time do you anticipate the Department on its own initiative would propose funding of the FMIT project?

The Department does not anticipate proposing funding of FMIT construction solely as a U.S. project.

The Department initiated funding of design and development of the FMIT project in FY 1978. We now recognize that it is likely that only one such facility will be necessary world-wide, that the FMIT would be sufficient for that particular purpose, and that the applied fundamental research data on fusion materials it would produce would become available to all. In this context, we believe it is appropriate that construction and use of the FMIT be undertaken as an international collaboration. Therefore, we have established the policy and so advised our potential international partners that we will proceed to construction given substantial international funding support, but that we will not proceed in the absence of such support.

QUESTIONS FROM SENATOR PAUL TSONGAS

1. The General Accounting Office has just completed a study of the magnetic fusion energy program. This study indicates that the Department of Energy is not pursuing the development strategy set forth in the Magnetic Fusion Engineering Act of 1980. Can the new DOE strategy be justified on other than a budgetary basis?

Yes, the new DOE strategy can be justified on other than a budgetary basis. There are a number of strategies that could be used to pursue the fusion program. These strategies can be distinguished by their technical risk, the cost effective use of resource, and the timing of the program relative to its desired endpoint, as well as budget. We believe that a strategy which prepares a sound scientific and technological base before extensive engineering development can be justified on its own merits.

2.

Why has this new strategy not been delineated in a comprehensive program management plan, which by law was to have been submitted to Congress by January 1982?

The comprehensive program plan for fusion is in the process of being evaluated by both DOE and the Executive Office and will be forthcoming to Congress within the next month.

3. When will we see this program management plan?

We are near final agreement and hope to have the plan finalized within a month.

4. According to the GAO report, DOE intends "to select a design concept in 1987 and then begin constructing an engineering test reactor that will be intermediate in size between what would have been the Fusion Engineering Device and the demonstration power plant." How is this very significant program change justified?

Without commenting on the dates in the GAO report the general justification is that the fusion program is continually making technical progress. As the time for beginning an engineering program slips, the capability of the program to design a more advanced device increases.

5. Given that a decision is to be made in 1987, the GAO notes that both the National Research Council in a recent report and DOE's Magnetic Fusion Advisory Committee in an October report question whether alternatives to the tokamak will be sufficiently developed for the selection to be other than a tokamak. Does the FY 84 budget request reflect a decision point on design in 1987, and if so, can you detail the program plans which will bring the alternate concepts up to a development level suitable for a proper selection to be made?

The Magnetic Fusion Advisory Committee has advised us that a decision in 1987 would be premature. We do not propose to make such a decision until after both the tokamak and tandem mirror systems have achieved reactor scale plasma operation. This is presently expected to be in 1985 - 1986 for the tokamak and 1987 - 1988 for the mirror. The FY 84 budget does not reflect a decision point on design in 1987.

6. DOE's Magnetic Fusion Advisory Committee in its October report concluded: "The Magnetic Fusion Advisory Committee recommends that DOE take immediate steps in the FY 84 budget process to restore program momentum and to return to an accelerated course of development. . ." It appears that DOE intends to ignore the recommendations of its own advisory committee. Why?

The MFAC is an advisory committee. The Department carries the responsibility of making program decisions on the basis of both their advice and many other factors such as priority of the fusion program relative to other national priorities within a limited budget.

7. The Committee also stated: "Based on continued technical progress in EBT-S and the findings of the EBT checkpoint review panel (July 1981), the Elmo bumpy torus is technically ready to proceed to the next development phase." Again, the Department seems to be ignoring its advisory council. In your response to a question from Senator Domenici you indicated that there were other than budgetary reasons for eliminating funds for the EBT-P project, the next phase for the EBT program. There seems to be a discrepancy between your testimony and the Committee report. Can you explain this variance?

The MFAC was not aware of new technical results from the EBT-S experiment which were only obtained in late 1982 after the MFAC report was issued. These results invalidated previous understanding about energy confinement mechanisms in the EBT concept. We decided a better data base was required before pursuing this large construction project. The MFAC further advised us not to proceed with this project on program priority grounds in the budget case closest to our Congressional request.

8. The National Research Institute report stated that: "The magnetic fusion program currently needs the strengthened technological base and enhanced attention to economic viability that industry can provide." Do you agree with this statement?

Yes, we agree with this statement and we are taking steps to strengthen industrial involvement for this purpose.

9. How do you account for the fact that, with the EBT-P project cancelled (it was to be built and operated by McDonnell Douglas Astronautics Corporation), the only private company under government contract to operate a DOE magnetic fusion facility is GA Technologies, Inc. (formerly General Atomic Co.). Are there plans to improve on this situation, to have future devices built and operated by industry? Do you feel that this should be a requirement for new endeavors?

We are endeavoring to involve private industry in the operation of both MFTF and TFTR under laboratory direction. Our experience does not indicate any advantage to the program in seeking to force operation of devices by industry since the capability already exists in the laboratories. We do seek maximum industrial involvement in device construction since industry possesses that capability. However, here again, joint projects with laboratories possessing the specialized scientific expertise seems most appropriate. Attempting to transfer the scientific expertise of laboratories to industry at this stage in the development of fusion is premature.

10. This summer John Marcum, Assistant Director for Energy and Natural Resources of the Office of Science and Technology Policy, at the June 22nd Industry-Government Seminar on Fusion Energy Development indicated that he did not believe that fusion would be a viable energy source within his or his children's lifetime, indicating a time frame near seventy years; furthermore, and as a result of the above, industry involvement in the program was premature. Is this the official opinion of the Administration, and do you plan to include this in the comprehensive program plan?

The Comprehensive Program Management Plan will address this issue. We do not believe certain types of industry involvement are premature. I believe Mr. Marcum was commenting on suggestions that industry take a leading role in the fundamental direction of the fusion program. We agree with the statement of the National Academy panel on this subject which I attach for the record.

Report by
The National Academy of Science Panel on Fusion

Participation of Industry

In the long run, the participation of industry will give form and purpose to the commercial applications of fusion power. Full participation requires both capital investment and provision of expertise.

The time at which fusion power can be commercially attractive and power plants can be marketed is far in the future--probably more than three decades even for demonstration plants; consequently capital investment at this time in expectation of a reasonable return on that investment is unrealistic. Short of capital investment, however, there are other useful forms of participation.

The fusion program needs the perspective and expertise found in industry in several areas--component supply, engineering services, and personnel exchange. Future benefits to the program as well as greater readiness of industry can be realized through increased industrial participation in defining requirements for fusion devices, in upgrading them, and in managing projects. Regarding components, through its procurement practices the program has access to the most qualified suppliers and their knowledge and experience. The program can engage by contract those industrial organizations with the knowledge, experience, and talent required for participation in conceptual design studies and technology development. The program can continue to encourage the assignment of engineers and scientists from industry to its various activities. This is an effective way for a company to keep abreast of developments in fusion for further involvement at the appropriate time.

The following general conclusion emerged concerning the needs of the program for industry participation:

The magnetic fusion program currently needs the strengthened technological base and enhanced attention to economic viability that industry can provide. Because profitmaking industry is not likely to invest substantial amounts of capital in fusion in the foreseeable future, this involvement will be largely through government-funded contracts, whether for the provision of components, engineering and managerial services, or personnel.

Some Views From the Larger Engineering Community

As noted earlier, a number of senior engineering executives from fields other than magnetic fusion were invited to the workshop to foster a stronger relation between the program and the larger engineering community. The discussion among workshop participants was limited by the short duration of the workshop, and many comments went beyond its original engineering focus. Nevertheless, some views were shared by several persons and thus deserve reporting here.

A majority of the senior engineering executives who attended concurred that the future engineering needs of fusion are well on their way to clear definition and none are of such a character so as to preclude solution. Generic pursuit of these needs is clearly necessary for progress in the program. The engineering needs for materials to be used in the severe plasma and nuclear environment of a reactor, along with those for the breeding, recovery, and control of tritium, were thought to warrant the greatest further identification and effort.

An important matter to address now is how to sustain a research and development program at an adequate level for the length of time needed to develop commercial applications of fusion. There was almost unanimous agreement that fusion is important as a potentially plentiful energy source. Nevertheless, views differed as to how rapidly fusion could be developed, irrespective of whether the pace will be limited by technology or by economics. In either case a long program of development is expected. Because the potential benefits of fusion are so great, the nation needs to exert its best efforts to satisfy program needs, especially where there may be applicability to other technologies.

Substantial technology development is required before selecting a fusion power concept and making systems engineering commitments. The development of particular technologies is necessary to support ongoing scientific programs as they continue toward demonstrating the scientific feasibility of fusion power. Until both scientific and technological development are much more complete, exclusive engineering choices, such as concept selection, might be based on inadequate data and understanding. Accordingly, continued attention to alternative concepts is prudent. The technology development sufficient to support experiments is not always sufficient for the future. Through the iteration of conceptual designs, together with experimental evidence, engineering needs can be continually defined and refined. The program's engineering development plan will need to be expanded to include the full performance testing and qualification of all components for fusion applications. Licensing and plant operating procedure requirements will need adequate attention. Given the possibility of advances in the science of fusion, fusion engineering must remain flexible.

A deuterium-tritium fusion device, perhaps at first lacking reactor-relevant technologies and reactor-grade plasma conditions, but certainly later incorporating them, will be absolutely essential to build the engineering understanding and data bases required for any successful application of fusion. It is extremely important to know at the earliest possible time how a fusing plasma actually behaves and how it can be controlled, and to have a fusion environment comprising neutrons, charged particles, and radiation. The fusion environment is needed for developing and testing materials and for generating data bases for engineering design.

Based on these considerations, the following general conclusion emerged concerning uncertainties in the timing, needs, support, and goal of fusion:

> The potential benefits of fusion-produced energy justify support for its continued development, although its goal and timing are still uncertain. Related needs for engineering and technology development are well defined and generic to several reactor concepts. Nevertheless, the actual developments put forward to satisfy these needs require proof in the rigorous environment of a reactor-grade plasma.

11. Why hasn't the FMIT been funded?

The Department has funded research, development and design of the FMIT since FY 1978. We have deferred funding of construction pending assessment and action by potential international partners to join, or not to join, in the construction and operation of the FMIT on a multinational basis.

We now recognize that it is likely that only one FMIT-like facility will be required world-wide and that the materials data it would generate will be needed by all and will become available to all. In this context, we believe it is appropriate that construction and operation proceed on an international basis. Potential partners have been advised that we will proceed with construction given substantial international funding support, but that we will not do so in the absence of such support.

12. What cooperative programs are being negotiated with other countries? Specifically, is there any plans for American participation in the Joint European Torus project, or Japan's JT-60?

The Department of Energy is currently negotiating potential new international fusion cooperation agreements with the People's Republic of China, Canada, the European Community, and an International Energy Agency, IEA, agreement involving the U.S., Japan, Canada, and the European Community.

The potential new agreement with China is in the last stage of negotiation prior to signature. It would establish a small, University-oriented exchange of an educational nature.

The negotiation with Canada is in an early stage. Canada has sent the Department a letter expressing interest in establishing a cooperative program and we are preparing a draft agreement. This potential cooperation would focus on a few specific areas where Canada has expertise comparable to our own; for example, tritium technology, remote handling, and plasma diagnostics.

The negotiation with the European Community is also in an early stage. However, in this case, we have a long standing, informal collaborative program in place covering all aspects of our current fusion research activities. The negotiations with the European Community would formalize the existing cooperative activities and establish a legal framework for more costly and complicated collaborations in the future.

The final negotiation currently under way is the consideration of whether the Fusion Materials Irradiation Test, FMIT, facility should be completed and operated as an IEA project. The U.S., Japan, Canada, and European Community are considering whether they should participate in this project. The four potential participating countries are engaged in a high level review of the desirability of this joint endeavor that may lead to an IEA agreement.

Concerning U.S. participation in the Joint European Torus, JET, and Japan's JT-60, both of these activities are under way. Our Tokamak Fusion Test Reactor, TFTR, project team has been holding yearly meetings with the JET and JT-60 project teams to trade information concerning design and construction problems and solutions. More recently the JET and TFTR teams have broadened their informal discussions to include their operating plans. This would be one of the topics included in a formal US/European Community fusion cooperation agreement, if one is established.

Between the JT-60 organization and the U.S., we are already in the process of setting up a formal joint planning committee under the existing U.S./Japan fusion cooperation agreement.

13. On the issue of CO_2 concentration in the atmosphere, you responded to a question by Senator Ford indicating that the estimated time to double the concentration to be 100 years. On what assumptions do you base this estimate?

The approximate pre-industrial CO_2 level, circa 1900, is assumed to be 300 parts per million. The doubling time then is the number of years to go from that pre-industrial level to 600 parts per million. The original prediction for reaching 600 parts per million was about 2025 based upon an annual rate of increase of 4 to 5%. The reduction in CO_2 emissions rates that I referred to earlier, to an annual rate of growth of less than 2% since 1973, now moves this further into the future by approximately 50-75 years. That is the basis for my statement that the doubling time of CO_2 is now likely to be approximately 100 years.

Department of Energy
Washington, D.C. 20585

May 19, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
  Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On February 28, 1983, Dr. Alvin Trivelpiece appeared before the Energy and Natural Resources Subcommittee on Energy Research and Development concerning the authorization for energy research programs.

Following the hearing, questions were submitted to Dr. Trivelpiece for response. On April 11, 1983, we sent you answers to the questions with the exception of question 5. The final report entitled "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950-1981", has been completed and is enclosed. This completes our response for that hearing.

A copy of the enclosed report has been sent to Mr. Astrin of the Committee.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas W. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bcc: Mr. Al Astrin
     Committee Staff

CARBON DIOXIDE EMISSIONS FROM FOSSIL FUELS: A PROCEDURE FOR ESTIMATION AND RESULTS FOR 1950-1981

by

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May 1983

This paper was prepared for the U.S. Department of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division under Contract No. DE-AC05-76OR0003. Major segments of the underlying analyses were completed under Gas Research Institute Contract No. 5014-361-0202.

EXECUTIVE SUMMARY

Measurements of atmospheric composition clearly demonstrate that the carbon dioxide concentration has increased by about 8 percent over the last 24 years (Keeling et al., 1982) and it is generally acknowledged that a major portion of the increase is related to the burning of fossil fuels. Although present in the atmosphere at only 338 parts per million (by volume), carbon dioxide absorbs infrared radiation in the wave lengths at which the earth radiates heat to space and experiments with general circulation models of the atmosphere indicate that a doubling of atmospheric CO_2 concentration would result in a rise in the mean earth surface temperature on the order of 2 to 3°C (see e.g., Manabe and Wetherald, 1980).

Because the growth in atmospheric CO_2 appears so closely tied to CO_2 emissions from fossil fuel burning and because the CO_2 issue has achieved considerable environmental significance, it seemed appropriate to review the analysis of Keeling (1973). The new data and revised methods attempt to reduce the uncertainties, and appear to make major modifications in the much used data set of CO_2 emissions from Rotty (1979, 1981) unnecessary.

The intent of this paper is thus two-fold: (1) to provide detailed documentation for a procedure to estimate CO_2 emissions from fossil fuels, and (2) to make independent and updated estimates of the rate at which fossil fuel combustion has released carbon dioxide in the atmosphere.

Carbon dioxide is an essential byproduct of fossil fuel burning, as seen in the equation

$$C_xH_y + (x + \frac{1}{4} y)\, O_2 \rightarrow x\, CO_2 + \frac{1}{2}\, y\, H_2O + \Delta H, \qquad \text{(Eq. 1)}$$

where ΔH is the heat of reaction and C_xH_y denotes a generalized hydrocarbon fuel. The calculation of CO_2 emissions is conceptually very simple. For each type of fuel, the annual global CO_2 emissions are the product of three terms: the amount of fuel produced, the fraction of the fuel that becomes oxidized, and a factor for the carbon content of the fuel. For CO_2 calculations, fossil fuels can conveniently be divided into the usual groups of gases, liquids, and solids. For each fuel group the annual fuel production (P) is multiplied by an estimate of the fraction of each year's fuel production that is oxidized (FO) and by an estimate of the average carbon content of each fuel group (C) to give the CO_2 emissions for that fuel group. That is,

$$CO_{2_i} = (P_i)(FO_i)(C_i) \qquad \text{(Eq. 2)}$$

where subscript i indicates a particular fuel group and CO_2 is expressed in units of mass of carbon.

An important outcome of this exercise is that an independent examination of the full computation of CO_2 emissions from fossil fuels has not discovered any fundamental oversights in the earlier methods of Keeling and of Rotty. Differences from the earlier results are minor, well within the uncertainty limits in the data available. The values presented Table E-1 and displayed in Figure E-1 show graphically the rate at which CO_2 emissions have been growing and the relative contributions of the various fuels.The figure illustrates the early dominance of the emissions from coal and the rapid increase in emissions from liquids between 1950 and 1980. The disruption of the growth in emissions that accompanied the dramatic change in energy prices and availability beginning in 1973 is clearly evident and appears to be mostly a consequence of reduced growth rate in the use of oil and gas.

The percentages shown in Figure E-1 are average exponential growth rates calculated by linear least squares fitting of the logarithms of the annual emissions. Although the trends indicated for the period following 1973 are based on only nine points, and hence are susceptible to some adjustment as additional years are added to the data, the change in growth rates around 1973 is quite evident. The pre-1973 4.5 percent annual rate of growth in CO_2 emissions from all fossil fuels has been reduced to less than half that. Carbon dioxide emissions from oil and gas show the 1973 change even more clearly. The apparent small increase shown in the growth rate in coal production following 1973 must be considered in terms of the relatively short period over which the rate was determined.

TABLE E-1. CO_2 EMISSIONS FROM FOSSIL FUELS, 1950-1981 (10^6T C)

Year	Gas Fuel	Liquid Fuel	Solid Fuel	Flared Gas	Total From Fossil Fuels
1950	97	423	1,075	23	1,618
1951	115	478	1,135	24	1,752
1952	124	504	1,124	26	1,778
1953	131	534	1,130	27	1,822
1954	137	557	1,119	27	1,840
1955	150	625	1,212	30	2,017
1956	161	679	1,277	32	2,149
1957	178	714	1,314	35	2,241
1958	192	732	1,340	35	2,299
1959	214	790	1,375	36	2,415
1960	235	850	1,426	39	2,550
1961	253	906	1,337	41	2,537
1962	276	982	1,368	44	2,670
1963	300	1,054	1,426	47	2,827
1964	328	1,138	1,478	51	2,995
1965	351	1,220	1,500	55	3,126
1966	380	1,323	1,522	60	3,285
1967	409	1,422	1,464	66	3,361
1968	445	1,551	1,494	73	3,563
1969	487	1,669	1,522	80	3,758
1970	516	1,834	1,576	88	4,014
1971	553	1,945	1,572	90	4,160
1972	583	2,054	1,585	95	4,317
1973	608	2,238	1,604	112	4,562
1974	616	2,245	1,613	107	4,581
1975	621	2,130	1,683	96	4,530
1976	645	2,308	1,727	110	4,790
1977	662	2,401	1,765	108	4,936
1978	692	2,424	1,786	106	5,008
1979	730	2,525	1,886	105	5,246
1980	739	2,413	1,916	102	5,170
1981*	780	2,246	1,941	93	5,060

* 1981 values are estimates by authors based on partial year data.

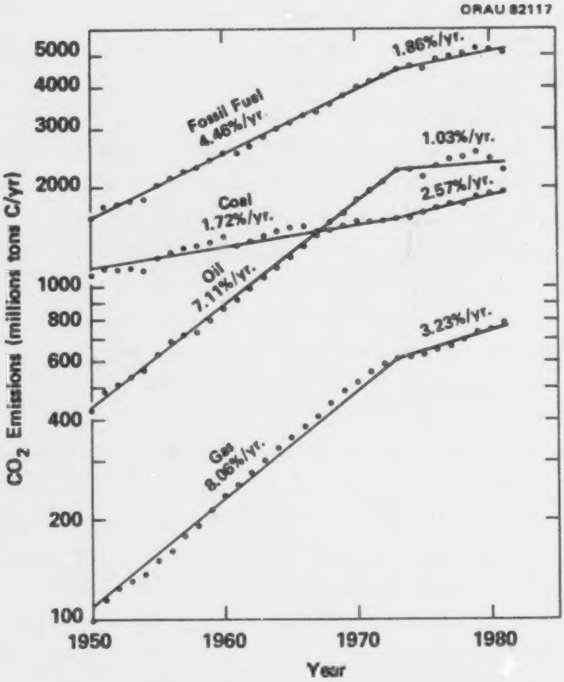

Figure E-1. Annual CO_2 Production from Each Fossil Fuel Group and Total Fossil Fuels.

This re-examination of procedures for calculation of CO_2 emissions had an additional result: estimates of the uncertainties in the final numbers. Because of the nature of the data used it has been impossible to quanitatively determine uncertainties and the authors have been left to estimate uncertainties based on subjective judgments of their own and of others who have worked with the data. In virtually all cases numbers have been closely bounded so that absolute errors cannot be large and errors in the time trends are even smaller. The largest absolute uncertainty enters the computation with the United Nations data set for fuel production but even here global fuel production is dominated by a small number of countries, most of which are believed to maintain and publish good statistical records.

Although the estimated uncertainty in the CO_2 emissions is about 10 percent, the trend of increasing emissions from fossil fuels is firmly established. There may be a small time-dependent error in the emissions calculation but the 1950-1973 annual growth rate cannot be far from the 4.5 percent per year calculated here and, although not yet well defined, it is clear that the long-term growth rate following 1973 is about half the earlier rate.

The development of the data set for CO_2 emissions depends on the three factors; fuel produced, fraction oxidized, and carbon content of the fuel, as indicated above. The calculations rely heavily on United Nations data for world fuel production. Global fuel production numbers published by the United Nations are consistent with numbers published elsewhere and represent the best efforts of a staff dedicated to the sole task of bringing together all of the available information. Fuel production data for any year are subject to revision as additional information becomes available but ultimately all data depend on the reporting of individual nations and production companies. The UN does present most of its data in energy rather than mass units, a great asset since there is a wide range of resource quality and hence composition. For each fuel type composition can be correlated with heating value.

For utility in calculating CO_2 emissions, fuel production numbers must be carefully defined. The quantity of interest for natural gas production is, for example, what the U.S. Department of Energy would identify as "marketed production" minus "extraction loss." Reinjected gas is not counted, flared gas is treated separately, and gas liquids are grouped with liquid fuels. Hence the "extraction loss" in gas processing is essentially a transfer to the liquid accounts. For liquid fuel production the simple sum of mass of crude oil and natural gas liquids is used because the carbon content is approximately the same for the two categories of liquid fuels. For coal, the UN has defined a "ton of coal equivalent" essentially as 29.31×10^9 joules and all coal has been adjusted for quality and compiled on this basis. Some confusion is created by the most recent UN publication relying on an unconventional definition of heating value for coal, but the intent is clear and calculations here compensate with a correction factor included in the carbon content term. The use of these units for the fuel produced determines the form, and to some extent the value, of the term used for carbon content.

Global data on flaring of natural gas have been published by official agencies only for 1971-1978 and even these are "partly estimated." These data from the U.S. Departments of Interior and Energy have been supplemented with the authors' estimates and by earlier published values of Rotty (1974). While these values are subject to considerable uncertainty (estimated at ±20 percent), they comprise only about 2 percent of the total CO_2 emissions.

Throughout this exercise it is clear that CO_2 emissions occur at fossil fuel use, not production, but that calculations are based on production. On an annual basis, however, production data can serve adequately if compensation is made for the uses of the material which do not result in oxidation of carbon--i.e., nonfuel use such as petrochemical feedstocks and asphalt, and in fuel use through losses to the environment and inefficiencies of combustion. Although either approach could be chosen, because production data are better and more straightforward than consumption data, this is the approach taken here. This choice requires that the terms for the fraction oxidized include consideration of both nonfuel use and incomplete combustion. Because the U.S. role in world fuel production has been so dominant (44 percent of total fossil fuel production in 1950, 22 percent in 1980) details of U.S. fuel use can provide a reasonable guide to global patterns for nonfuel use as well as for efficiency of combustion. Information on the breakdown of use of fuel material for nonfuel use is very limited for many parts of the world and therefore the procedures developed and used here start with a U.S. pattern and are adapted as seems appropriate to the global scale.

Selection of factors for fraction oxidized (FO) requires some effort to acknowledge that fuel which is produced but not oxidized this year will nonetheless be oxidized over a period of some years, the rate dependent on how the material is used and ultimately disposed of. It is estimated here that the quantity of natural gas oxidized in any year, including continuing oxidation of products from previous years, is equivalent to 98 percent of current year production; for liquid and solid fuels this factor is 91.8 percent and 98.2 percent respectively. The smaller number for liquid fuels is because of wide usage for paving materials, plastics, synthetic fibers, lubricants, etc. The uncertainty adopted for nonfuel use of liquids (ranging from 4.7 to 8.7 percent) is near a factor of two, but the uncertainty imposed on the subsequent calculation of CO_2 emissions is only ±2 percent. The fraction oxidized has probably been changing with time, and this could introduce uncertainty. The efficiency of fuel burning has almost certainly been increasing, resulting in a small overestimation of CO_2 in the early years. However, the nonfuel use of fuels has probably been increasing and the time-dependent bias in the trend of CO_2 emissions numbers from this effect is opposite to that of improved combustion.

There is no systematic tabulation of the carbon content of fuel produced all over the world, but having fuel production numbers in energy units makes it straightforward to estimate carbon content. Analysis of a broad sampling of world analytical data and conversion to units compatible with UN fuel production numbers gives the following factors for the mean carbon content of fuels: gases, 13.7 tons C per 10^{12} joules (510 g/m^3); liquids, 0.85 tons C per ton fuel; and solids, 0.746 tons C per ton coal equivalent. The factor for coal is uniquely appropriate for use with UN tabulated values for tons of coal equivalent (defined for "net heat value"). The factor includes an adjustment to make the UN definition of heating value compatible with coal compositional data available from other sources.

Estimates of uncertainty in these calculations are highly subjective, and appreciation of this fact is essential. Full understanding of the increase in atmospheric CO_2 requires that historical data of CO_2 emissions be used along with data describing other portions of the carbon cycle. Some measure of uncertainty is important and the authors attempt to increase the value of the results by providing 90 percent confidence limits on the calculated emissions. This effort is summarized in Table E-2. As indicated in the Table each annual total presented in Table E-1 is estimated to have an uncertainty of between 6 and 10 percent. However, because data from successive years are highly correlated, the year-to-year changes are probably known with much greater accuracy than the individual annual values.

TABLE E-2. UNCERTAINTIES IN CO_2 EMISSIONS (%)

	E_1 Fuel Produced (P)	E_2 Fraction Oxidized (FO)	E_3 Carbon Content (C)	Emissions* $\sqrt{\Sigma E_j^2}$	Weighted** Emissions $f_i \sqrt{\Sigma E_j^2}$
Gases	10	1	2	10.25	1.47
Liquids	8	3	1	8.60	4.01
Solids	11.2	2	2	11.55	4.28
Gas Flared	20	1	3	20.25	0.41

Total Uncertainty:

a. If uncertainties for the individual fuels are mutually independent. $[\sum(f_i \sqrt{\Sigma E_j^2})^2] = 6.06$

b. If uncertainties for the individual fuels are not independent. $\sum f_i \sqrt{\Sigma E_j^2} = 10.16$

* E_j is the uncertainty in the factors P, FO, and C for a given fuel type i.

** Weighted by 1980 weighting factor f_i = 1980 emissions from i th fuel type divided by total 1980 emissions.

THE PROBLEM

In attempting to identify the possible causes and consequences of the observed increasing atmospheric CO_2 concentration, the source of the CO_2 is a major concern. Through the past several decades, the combustion of fossil fuels has grown immensely and it is clearly an important source of CO_2.

The intent of this study was two-fold: (1) to provide detailed documentation for a procedure to estimate CO_2 emissions from fossil fuels, and (2) to make independent and updated estimates of the rate at which fossil fuel combustion has released carbon dioxide to the atmosphere. The CO_2 issue has achieved such significance that it is appropriate to review the analysis of Keeling (1973) and affirm that the much used data sets of CO_2 emissions from Rotty (1979, 1981), using Keeling's procedure, do not contain significant oversights. This work is intended to provide independent and updated estimates of CO_2 emissions and undue significance should not be attached to minor differences from previously published values.

The result of the calculations described here will be a table which displays, for the period 1950 through 1981, the amount of fossil fuel produced and the amount of CO_2 discharged to the atmosphere as a consequence. A final graph will display, for each fuel and for the global total, how CO_2 emissions have varied as a function of time.

RATIONALE

The calculation of CO_2 emissions from fossil fuels is conceptually very simple. For each type of fuel, the annual CO_2 emissions are the product of three terms: the amount of fuel produced, the fraction of the fuel that becomes oxidized, and a factor for the carbon content of the fuel. For CO_2 calculations, fossil fuels can conveniently be divided into the usual groups of gases, liquids, and solids. For each fuel group we start with annual fuel production data(P). Multiplying P by the fraction of each year's fuel production that is oxidized (FO) and by the average carbon content of each fuel group (C) will give the CO_2 emissions for that fuel group. That is,

$$CO_{2_i} = (P_i)(FO_i)(C_i) \qquad \text{Eq. 1}$$

where subscript i indicates a particular fuel group and CO_{2_i} is expressed in mass of carbon.

The data for annual fuel production must recognize that all coal (or natural gas or crude oil) is not of the same composition, and thus may have varying energy content and CO_2 potential. It is easiest to accomplish this by using fuel production data in either energy or energy equivalent units (for example, tons of coal equivalent).

The second factor in Equation 1, the fraction becoming oxidized, requires examining the use of fuels. For coal, nearly all the production at present is for combustion, and the effectiveness of the combustion process determines the fraction of the carbon that is oxidized. For liquids and gases we must account not only for inefficient combustion but also for nonfuel uses. Derivation of this factor for each fuel group is based on data for the products of petroleum refineries and natural gas processing plants.

There is no systematic tabulation of data on the carbon content of fuel produced all over the world. For liquid fuels and for natural gas the hydrogen-carbon ratio largely determines the heating value and for solid fuels most of the combustion energy is from oxidation of carbon. Thus for each fuel the heating value is closely correlated to the carbon content and the energy equivalence concept used in the tabulation of production data makes it possible to deduce fuel composition quite accurately.

The final term in Equation 1 is a factor which relates carbon content to energy content for each fuel group. The complete combustion of a fossil fuel can be represented by

$$C_xH_y + (x + \frac{1}{4} y)\ O_2 \rightarrow x\ CO_2 + \frac{1}{2} y\ H_2O(\text{gas}) + \Delta H_L$$

or

$$C_xH_y + (x + \frac{1}{4} y)\ O_2 \rightarrow x\ CO_2 + \frac{1}{2} y\ H_2O(\text{liquid}) + \Delta H_H$$

where ΔH is the heat of reaction and C_xH_y denotes a generalized fuel. For combustion of hydrocarbons the heat of reaction is negative in the thermodynamic sense, meaning that heat is given off. When all the water in the products of combustion is liquid (for combustion at relatively low temperature) the higher (or gross) heating value, ΔH_H, is appropriate. ΔH_H is always greater than the lower (or net) heating value ΔH_L because of the energy required in the vaporization of water. Real fuels vary considerably in composition--both in time and place--hence x and y are different not only for average natural gas and petroleum, and for different petroleum products (gasoline vs. fuel oil), but also for crude oil from different fields. This makes development and use of global averages very important and is accomplished by using the energy equivalence basis, i.e. the implicit relations between ΔH and x and y.

In the past, CO_2 emissions have often been based on United Nations fuel production data using similar procedures (described by Keeling [1973] and Rotty [1973]). During the past decade the United Nations statistical office has modified their reporting toward a more consistent fuel equivalence basis. This has necessitated modifications in the procedures for calculating CO_2 emissions to assure consistency. Most recently, Rotty (1982) calculated the global emissions from fossil fuel for the years 1950-1979 and estimated 1980 emissions from incomplete data. In the final section of this report is an updated version of these emissions computations and an estimate for 1981.

FUEL PRODUCTION DATA

In approaching calculations of carbon dioxide emissions it is useful to begin by examining the first term on the right in Equation 1. A consistent set of global fuel data is clearly required and the form of the other two factors will be dictated by the definitions and accounting units used in the fuel production data.

Most investigators calculating the production of carbon dioxide from fossil fuels have relied on data published by the United Nations. The U.S. Bureau of Mines, the Energy Information Administration of the U.S. Department of Energy, the World Bank, the Organization for Economic Cooperation and Development, and numerous other national and international organizations also maintain data on fuel use and energy activities. The UN Statistical Office energy unit offers the most complete and consistent time series for global fossil fuel production and consumption, partly because information from the other sources is used in the development of the UN data, but most important because the UN data set is continually modified and updated. The reliability of the data (and the suitability of its use in CO_2 calculations) has consistently improved through the years as more information has become available to the UN staff and as energy information has become more important in world activities.

Although the United Nations data are now in relatively consistent energy or energy-equivalent units, the nature of our computations and common usage in the various disciplines insure that a mixture of units of measure are encountered. Despite the potential for confusion with mixed units, we believe it important to distinguish between data taken from other sources and data which have been manipulated by us. Most data are thus presented in the units of the initial compilation and any manipulations requiring, for example, mass to volume or mass to energy-content conversions are carefully documented. Throughout this document "tons" should be understood to be metric tons.

Production of Natural Gas

Although we are interested in global data, the pattern for gas production and distribution in the U.S. is useful to help understand terms and processes. Figure 1 has been prepared from data published by the Energy Information Agency of the U.S. Department of Energy and shows the 1980 flows of natural gas in the United States. In calculating the CO_2 emissions we must account for all the gas that is withdrawn from wells and becomes oxidized. Gas reinjected into the earth to repressure oil wells should not be counted and we will account separately for gas vented and flared. Hence "marketed production" is our starting point. The tabulations illustrated in Figure 1 permit accounting for the loss of gas volume during processing for recovery of liquids ("extraction loss"). The systematic approach of combining liquids extracted from natural gas with other liquid fuels has been adopted here. To avoid counting this quantity twice the basic number we must consider in our analysis of CO_2 emissions from gas is the marketed production minus the extraction loss. In fact, this is the number now recorded by the UN Statistical Office as natural gas production. The UN Statistical Office reports this natural gas production for all the producing countries.

Of course all of the gas produced in a given year is not necessarily consumed in the same year. One reason for this is net changes in storage, but the numbers shown as "to storage" and "from storage" in Figure 1 show that for 1980 the error on this account is less than 1 percent in the U.S. Over periods of very few years the changes in storage will tend to balance and global totals of imports and exports should also balance. Figure 1 suggests another issue which cannot be neglected by balancing over a few years or integrating over the whole globe. Some fraction of the industrial-use gas is for non-fuel uses and will be oxidized over time periods ranging from essentially immediate to decades. These uses include, for example, ammonia and methyl alcohol production and a variety of other petrochemical feedstock requirements. In the following section we will make allowance for the fraction of fuels produced but not oxidized.

In their early fuel data the UN tabulated natural gas production in cubic meters, counting gases with widely varying compositions on the same basis. Natural gas data were later changed to reflect the energy content of the gas and were tabulated in teracalories. Beginning with the publication of the 1979 Yearbook of World Energy Statistics the data are given in terajoules. The UN has converted all the published gas data (i.e., back to 1950) to the terajoule basis. Because the carbon content is closely

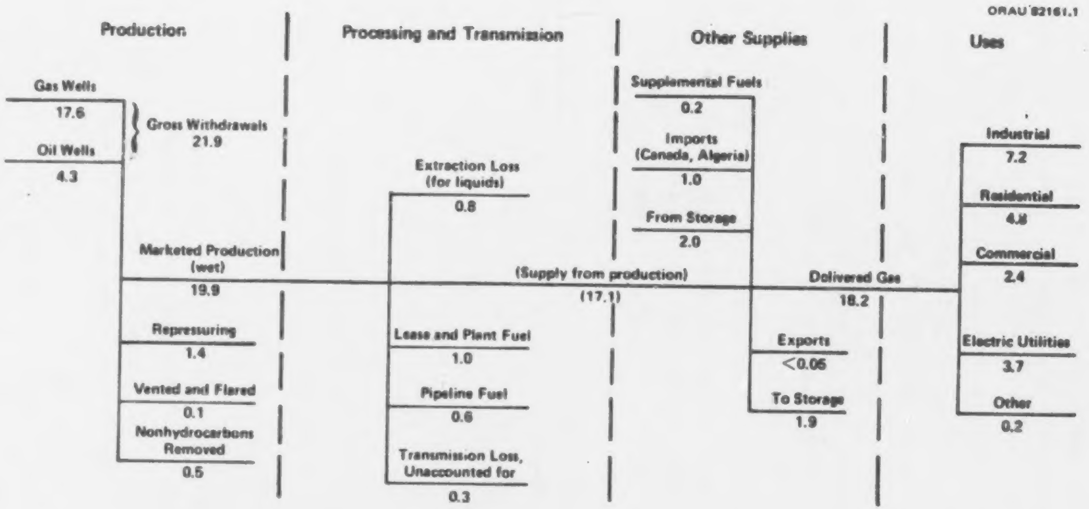
ORAU 82161.1
Production
Processing and Transmission
Other Supplies
Uses
Gas Wells
17.6
Oil Wells
4.3
Gross Withdrawals
21.9
Marketed Production (wet)
19.9
Repressuring
1.4
Vented and Flared
0.1
Nonhydrocarbons Removed
0.5
Extraction Loss (for liquids)
0.8
Lease and Plant Fuel
1.0
Pipeline Fuel
0.6
Transmission Loss, Unaccounted for
0.3
(Supply from production)
(17.1)
Supplemental Fuels
0.2
Imports (Canada, Algeria)
1.0
From Storage
2.0
Exports
<0.06
To Storage
1.9
Delivered Gas
18.2
Industrial
7.2
Residential
4.8
Commercial
2.4
Electric Utilities
3.7
Other
0.2

Figure 1. U.S. Flows of Natural Gas, 1980 (in 10^{12} cubic feet; 1ft^3 ≈ 0.028317 m^3)
Data from *Natural Gas Annual, 1980,* U.S. DOE, (1982a).

correlated with the heating value of the gas, we believe that this has improved the estimates of CO_2 emissions from natural gases.

Many of the UN data sets for natural gas are received in the statistical office in energy units. That is, in response to the UN questionnaires, the individual countries (or organizations acting on behalf of individual countries) submit natural gas data in terms of the energy content of the gas. The UN maintains a reference table of heating values for gas from each country, but it must be pointed out that these values are not usually used in making volume to energy conversions in the UN office. Although it is not always clear, most of these values are as reported by the individual countries, and most appear to be based on higher heating values of the fuel. We will use these conversion factors to characterize the carbon content of natural gas. The most recently revised UN data for natural gas production during the period 1950-80, are given in our summary Table 14, column 1. Because the gas industry has been so tightly regulated, recent gas production numbers for the U.S. are likely to be correct within ± 5 percent. Non-U.S. production numbers are less accurate but we suggest that the figures for annual global totals are within ± 10 percent. Our confidence in the global figures is enhanced by recognition that the quality of the data should be improving with time, and the historic data are heavily dominated by U.S. production. It was in 1974 that U.S. production first dropped below 50 percent of the world total and as recently as 1960 U.S. production of natural gas exceeded 75 percent of the world total.

Production of Liquid Fuels

As in the case of natural gas, the global production and use of liquid fuels can be viewed through the analog of the detailed flow of liquid fuels for the United States. Based on data from the Energy Information Administration of the U.S. Department of Energy, the 1981 mix and flow of liquid fuels in the U.S. can be depicted as in Figure 2. Note that liquids derived from natural gas are treated here as a separate production source.

Just as with natural gas, imports and exports do not have to be considered if CO_2 emissions are based on global fuel production. However, if interest is on the distribution of CO_2 emissions among countries (or parts of the world), different procedures must be considered. The distribution based on consumption will be drastically different from the distribution based on production, because such a large fraction of the crude petroleum produced is involved in international trade. On the other hand, because the net change in stocks is a small number, using total production numbers to indicate total consumption and CO_2 emissions introduces negligible error.

As indicated in Figure 2, most of the liquids are used as fuels and hence oxidized within a relatively short time of production. However, the use of production data for liquid fuels in computing CO_2 requires a correction for the liquids that are not oxidized in their use. Nonfuel uses of petroleum liquids come primarily under the "other" category in the last column of Figure 2 and it is here that major adjustments will be made.

The United Nations combines U.S. Department of Energy statistics with official or unofficial tabulations from other nations to arrive at world production statistics for crude petroleum and for natural gas liquids. As in the case of natural gas, the UN data are taken to be the best available for our purposes because of their completeness, historical consistency, and clear conformity with other available data. The UN production data for liquids, like those for other fuel types, are widely quoted by others and are essentially identical to "independent" values published elsewhere (see, for example, Table 1). The agreement of the UN data with data published by other organizations does not imply that the data are accurate to a limit described by these variances. Frequently the primary sources are identical, and some of the differences are due to interpretations and assumptions about standards.

In considering sources of error in the data on liquid fuels, an area of concern is the handling of natural gas liquids. These liquids comprise a mixture of compounds, some of which are used directly as fuel or chemical feedstocks and some of which are combined with crude petroleum or its intermediate products in refineries. On the average, natural gas liquids (NGLs) have a lower carbon-to-hydrogen ratio than crude petroleum, and thus, on a per unit mass basis, a higher energy content. Because the UN data on liquid fuels are designed to be representative of the energy content of the fuel, their liquid fuel data set (on an energy equivalent basis) is compiled by multiplying NGLs by 1.06032 and then adding to the crude petroleum

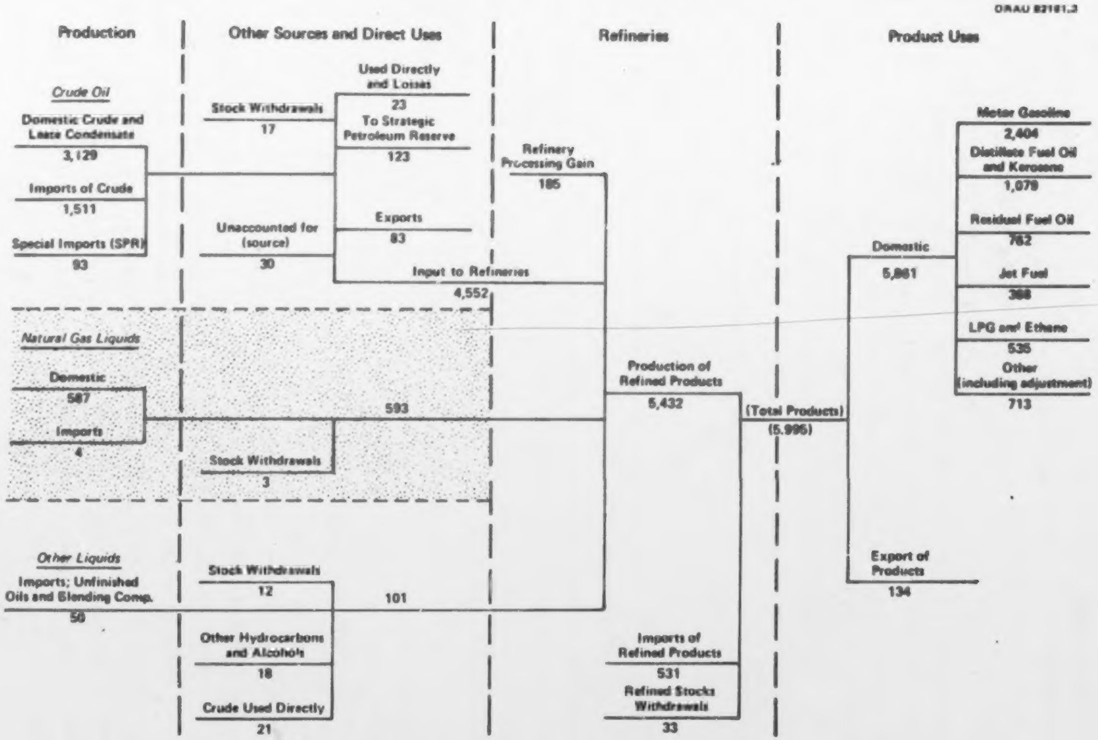
ORAU 82181.3
Production
Other Sources and Direct Uses
Refineries
Product Uses
Crude Oil
Domestic Crude and Lease Condensate
3,129
Imports of Crude
1,511
Special Imports (SPR)
93
Stock Withdrawals
17
Used Directly and Losses
23
To Strategic Petroleum Reserve
123
Unaccounted for (source)
30
Exports
83
Input to Refineries
4,552
Refinery Processing Gain
185
Natural Gas Liquids
Domestic
587
Imports
4
593
Stock Withdrawals
3
Other Liquids
Imports; Unfinished Oils and Blending Comp.
50
Stock Withdrawals
12
101
Other Hydrocarbons and Alcohols
18
Crude Used Directly
21
Production of Refined Products
5,432
Imports of Refined Products
531
Refined Stocks Withdrawals
33
(Total Products)
(5,996)
Domestic
5,861
Motor Gasoline
2,404
Distillate Fuel Oil and Kerosene
1,079
Residual Fuel Oil
762
Jet Fuel
368
LPG and Ethane
535
Other (including adjustment)
713
Export of Products
134

Figure 2. U.S. Flows of Liquid Fuels, 1981 (millions of barrels; 1 barrel ≈ 0.135 tons)
Data from *Petroleum Supply Annual, 1981*, DOE/EIA-0340 (81)/1, (1982b).

TABLE 1. WORLD CRUDE OIL PRODUCTION
AS REPORTED BY DIFFERENT SOURCES*
(10^6 tons oil equivalent)

	1980 Yearbook of World Energy Statistics (a)	Enright, Vielvoye & Beck (b)	U.S. CIA (c)	API (d)
1980	2,986	2,974	2,974	
1979	3,127	3,122	3,134	
1978	3,012	3,011	3,011	3,033
1977	2,985	2,982	2,987	2,998
1976	2,870	2,872		2,901
1975	2,644	2,651		2,669
1974	2,789	2,795		2,811
1973	2,780	2,793		2,788
1972	2,548	2,514		2,546
1971	2,413	2,394		2,418
1970	2,275	2,266		2,288

(a) 1980 Yearbook of World Energy Statistics, U.N., (1982), and Data Tape of UN Energy Statistics, Carbon Dioxide Information Center, Oak Ridge National Laboratory.

(b) From Enright, Vielvoye, and Beck (1981).

(c) From U.S. Central Intelligence Agency (1981).

(d) From American Petroleum Institute (1981).

* All data (except UN) were reported in barrels or barrels per day and were converted to tons oil equivalent by assuming a mean gravity of 32.5° API.

production. The factor 1.06052 is the correction factor to reflect that the NGLs have a 6.052 percent greater heating value per unit of mass than average crude petroleum.

For the purpose of calculating CO_2 emissions, we do not wish to employ this weighting factor introduced to account for more hydrogen in the fuel, so have adopted the procedure of simply adding the mass of natural gas liquids to the mass of crude petroleum. On the assumption that crude petroleum contains 85 percent carbon (see discussion below regarding carbon content of crude petroleum) and that NGLs contain between 80 and 84 percent carbon (C_2H_6 is 80 percent carbon, C_7H_{16} is 84 percent carbon), the error in considering the combination as all crude is very small. For the world as a whole, the mass of NGLs is about 3 percent of the mass of crude petroleum production. The carbon fraction for the mixture should be about

$$(0.97)(0.85) + (0.03)(0.82) = 0.8491,$$

which is so close to the carbon fraction of crude petroleum as to make any error from the combination procedure negligible. However, in the future, as more liquids are captured from natural gas and as the mixture of natural gas liquids shifts toward lighter compounds, consideration might be given to revising the procedure of simply adding data for NGLs to data for crude production. At present the most appropriate liquid fuel data for our purpose are obtained by adding the UN data for mass of crude petroleum to the UN data for mass of natural gas liquids. The result for world liquid fuel production is given in column 3 of the summary table (Table 14).

The global accounts for world production of liquid fuels consist of data for many parts of the world. In some cases these data appear to be highly reliable, e.g. OECD nations, but in others where smaller resources are committed to documentation, the data are less reliable. The UN staff has attempted to evaluate the reports and make appropriate adjustments when evidence warrants, but quantifying the reliability is impossible. Because most of the crude oil is produced in a relatively few countries and because the value of each unit of oil has become so high, we believe that since 1974 the world oil accounts involve uncertainty that does not exceed some ±8 percent, and would be better if data from Iran and Iraq were more reliable. Before the higher prices and more careful accounting resulting from the 1973-74 embargo, the uncertainty could have been more, but at that time the data from Iran were much better than now, and the data from the U.S.A., U.S.S.R., and Saudi Arabia have probably been consistently reliable. Information now available is inadequate to allow formal calculations of uncertainties for global petroleum production. We estimate the data for the period before 1974 to contain an uncertainty of ±10 percent.

Production of Solid Fuels

Coal is an immensely variable commodity; both its heating value and carbon content vary over wide ranges. The ASTM scheme for classification of coals by rank (Table 2) makes it clear that tons of "coal" is not a fully adequate value for establishing how much carbon is likely to be released during burning. We need, in addition, some indication of the quality of the coal and this is basically what the UN Statistical Office has tried to achieve in reporting tons of coal equivalent. The UN basis for coal equivalency comprises 7000 calories per gram (29.31×10^9 joules/ton).

Adopting United Nations data for coal production subsumes most of the questions about coal quality in the coal production numbers. When the UN reports coal production in units of tons of coal equivalent, they have already made the conversion, in energy-equivalent units, from a ton of, say New Zealand brown coal, to tons of coal equivalent. We consider how well the UN standard of 7000 cal/g represents average coal.

That 7000 cal/g is an appropriate base for coal equivalents is supported by the compilaton of Zubovic et al. (1979), who summarized analytical data on 617 bituminous coal samples from the eastern U.S. The arithmetic mean heating value came out to be 7090 cal/g (12,670 Btu/lb), the geometric mean heating value 6996 cal/g (12,590 Btu/lb). An earlier study by Swanson et al. (1976) led to a mean heating value at 6812 cal/g (12,260 Btu/lb) for 277 bituminous coal samples. The U.S. Bureau of Mines has consistently used a heating value of 7057 cal/g (12,700 Btu/lb) for anthracite.

U.S. Bureau of Mines and U.S. Department of Energy data show the decreasing higher heating value of bituminous coal and lignite produced in the U.S. (Table 3). The U.S. value has been below 7000 cal/g since 1967 as the electric utility industry has increased use of western coals with

TABLE 2. CLASSIFICATION OF U.S. COALS BY RANK

Class	Group	Fixed Carbon Limits, % (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, % (Dry, Mineral-Matter-Free Basis)		Calorific Value Limits, Btu/lb* (Moist, Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracitic	1. Meta-anthracite	98	—	—	2	—	—	Nonagglomerating
	2. Anthracite	92	98	2	8	—	—	
	3. Semianthracite	86	92	8	14	—	—	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	—	—	Commonly agglomerating
	2. Medium volatile bituminous coal	69	78	22	31	—	—	
	3. High volatile A bituminous coal	—	69	31	—	14,000	—	
	4. High volatile B bituminous coal	—	—	—	—	13,000	14,000	
	5. High volatile C bituminous coal	—	—	—	—	11,500 10,500	13,000 11,500	Agglomerating
III. Subbituminous	1. Subbituminous A coal	—	—	—	—	10,500	11,500	Nonagglomerating
	2. Subbituminous B coal	—	—	—	—	9,500	10,500	
	3. Subbituminous C coal	—	—	—	—	8,300	9,500	
IV. Lignitic	1. Lignite A	—	—	—	—	6,300	8,300	
	2. Lignite B	—	—	—	—	—	6,300	

From: ASTM (1974).

* 12,600 Btu/lb = 7,000 cal/gm = 29.31 x 10^9 joules/ton.

TABLE 3. DECREASING HEATING VALUE OF PRODUCED U.S. COAL

	Higher (gross) heating value[a] (cal/g)		Lower (Net) heating value[b] (cal/g)	
1980		(6,292)[c]	5,860	(5,977)[c]
1979	6,234	(6,284)[c]	5,860	(5,970)[c]
1878	6,234	(6,395)[c]	5,880	(6,075)[c]
1977	6,307		5,910	
1976	6,428		6,110	
1975	6,446		6,120	
1974	6,589		6,260	
1973	6,669		6,340	
1972	6,682		6,350	
1971	6,734		6,400	
1970	6,829		6,490	
1969	6,918		6,570	
1968	6,962		6,610	
1967	6,990		6,640	
1966	7,029		6,680	
1965	7,062		6,710	
1964	7,085		6,780	
1963	7,090		6,740	
1962	7,107		6,750	
1961	7,107		6,750	
1960	7,129		6,770	
1959	7,135		6,780	
1958	7,218		6,860	
1957	7,218		6,860	
1956	7,218		6,860	
1955	7,223		6,860	
1954	7,223		6,910	
1953	7,223		6,910	
1952	7,223		6,910	
1951	7,223		6,910	
1950	7,223		6,910	

a. 1973-1979 data from U.S. Department of Energy (1980a); 1972 and prior from U.S. Bureau of Mines, 1976.

b. Used by UN Statistical Office in preparation of 1980 Yearbook of World Energy Statistics (UN, 1982).

c. 1978-1980 data in parentheses are from Annual Bulletin of Coal Statistics for Europe (UN, 1981).

reduced heating values. Coal used at large U.S. electric power plants (>25 MW) had an average heating value of only 6078 cal/g (10857 Btu/lb) in 1976 and 6175 cal/g (11027 Btu/lb) in 1977 (National Coal Association, 1978). To have the reported amount of coal truly reflect the annual energy use (and carbon content), the United Nations has countered the decreasing heating values by applying correction factors to lower grade fuels and reporting coal equivalent tons.

Beginning with the publication of World Energy Supplies 1973-78, (identified by the UN as Series J, No. 22) in 1979, the UN staff has made efforts to insure that all coal is adjusted to coal equivalents. Between 1973 and 1979 there were adjustments for low grade hard coals in Norway, United Kingdom, Czechoslovakia, New Zealand, U.S.S.R., India, Pakistan, German Democratic Republic, and Hungary (UN, 1979). Prior to 1973 there was adjustment only for U.S.S.R. and Pakistan. Table 4 shows the progressive changes in world coal production reported by successive UN annual volumes. The World Energy Supplies series published prior to 1979 (J-19, J-20, J-21), indicate the changes made as a result of additional information or revisions of individual country data. Beginning with the World Energy Supplies (J-22), changes in the data are larger and consistently downward, reflecting the adjustments for reduced heating value of coals from more and more countries.

The changes between times of publication of J-22 and the 1979 Yearbook of World Energy Statistics (published in 1981) included not only downward adjustment made for lower grade coals, but also a beginning of a change from a higher heating value to a lower heating value basis ("gross heat value" to "net heat value," in UN terms). Thus, for example, the reduction in the value reported for 1975 between J-22 and the 1980 Yearbook is 246 million tons of coal equivalent (9.5 percent) and is the result of a combination of further adjustments for coal quality plus adjustment to "net heat value." The UN has now completed the shift to a "net heat value" basis for at least 60 percent of the world coal production. It appears that the coefficient to convert Chinese coal to coal equivalents also is on a "net heat value" basis and this would raise the percentage to 77 of the total world production. Table 3, column 2, gives the heating values used by the UN (1982) when converting tons of U.S. coal to tons of coal equivalent.

TABLE 4. WORLD COAL PRODUCTION AS REPORTED BY THE UNITED NATIONS STATISTICAL OFFICE IN SUCCESSIVE ANNUAL REPORTS
(in millions of tons of coal equivalent)

	UN World Energy Supplies (annual volumes)				UN Yearbook of World Energy Statistics	
	J-19	J-20	J-21	J-22		
Year	1950-74*	1971-75*	1972-76*	1973-78*	1979+	1980+
1979					2737	2614
1978				2784	2608	2476
1977			2775	2763	2570	2447
1976		2714	2702	2650	2482	2393
1975	2634	2640	2633	2577	2427	2331
1974	2513	2517	2503	2457	2325	2234
1973	2481	2483	2470	2426	2308	2220
1972	2439	2438	2426	2384	2275	2191
1971	2398	2397	2395	2362	2256	2173
1970	2420	2397	2399	2356	2260	2179

* Annual edition of *World Energy Supplies*, United Nations.

+ Annual edition of *Yearbook of World Energy Statistics* (replaces *World Energy Supplies*), United Nations.

The UN decision to tabulate coal production on a "net heat value" basis complicates the computation of CO_2 emissions because most coal analytical data provide chemical composition and higher heating value. However, because the UN publications provide the most reliable and consistent set of global data for coal, we will continue to rely on them and make adjustment in the factor for the carbon content to accommodate the UN use of "net heat values."

In using the UN solid fuels values from the 1980 Yearbook of World Energy Statistics, one specific inconsistency was noted. Because the data published are based on coefficients converting to coal equivalents for all major coal producers except Poland, we have adjusted the world totals to reflect the application of such a coefficient (0.810) to Polish coal. This procedure was adopted after lengthy discussions with UN statistical office staff and we are assured that future UN data will likewise use a coefficient near 0.810 for Polish hard coal data. Thus the UN data for solid fuel production (as slightly modified) are the base used in calculating CO_2 emissions. These modified production data for solid fuels are in column 5 of the summary table (Table 14).

The estimation of uncertainty in the solid fuel data, already difficult, is made even more so because the process of revising the coefficients for coal equivalents is still in progress at the UN (but appears to be nearing completion). With some uncertainty still associated with the change to net heat value, we judge these data to include an uncertainty around 11 percent. This is based on an uncertainty of ± 5 percent for the production data in mass units and ± 10 percent on the conversion to a coal equivalence basis. Collecting these as $\sqrt{\Sigma E_i^2}$ where the E_is are the individual uncertainty estimates, we have $\sqrt{100 + 25} = 11.2$ percent.

Flaring of Natural Gas

The lack of markets and infrastructure for using natural gas as a fuel leads to massive flaring at oil fields in some remote locations. The UN makes no attempt to tabulate the amounts of natural gas flared from any nation. Data for non-U.S. levels of natural gas flaring prior to 1971 are nonexistent. To develop a usable data set, Rotty (1974) used unpublished gas flaring data for 1968-1971 (included on questionnaires returned to the U.S. Bureau of Mines) with published oil production data from many countries to estimate a time series for gas flaring. Rotty assumed that essentially all gas flared is "associated gas" from oil fields where facilities for the recovery of the gas are not present and used the ratio of gas flaring to oil production for separate areas of the world. Although Rotty's numbers are somewhat speculative, they contribute a small fraction of the total emissions and are used here for the period 1950-70 without change.

Beginning about the time of Rotty's estimates, the U.S. Department of the Interior, and more recently the Department of Energy, have published annual values for the global flaring of natural gas. We use these data for the years 1971 through 1978 (DOI 1974; DOE, 1979; DOE, 1980b) but note that the published values are labeled "partly estimated." This data set appears fully compatible with the estimates of Rotty (1974) and this combination provides the best available consistent data sequence for global gas flaring (see Table 14).

Although there is no strong incentive to account for gas flaring, the recent data represent an attempt to account for this loss. Formal calculation of the uncertainty involved in these data would require more information than is available. The flaring of gas associated with oil production is at best as uncertain as the oil production, but the approximate agreement of the estimates of Rotty (1974) with attempts by DOE to tabulate a time sequence of recent global flaring suggests the uncertainty is not unbounded. We lack great confidence in all flaring data (earlier values in particular) and believe an uncertainty of ± 20 percent is appropriate here.

Production Data vs. Consumption Data

Carbon dioxide is emitted when fossil fuel is oxidized, i.e., consumed. Global fuel accounts are published as both fuel production and fuel consumption. The difference is not simply an increase or decrease in storage, but includes adjustments for various amounts of the fuel produced that are employed in many different end uses. In addition to use as common fuels and in processing fuels, some is used as special fuel, some as "nonfuel" in which the carbon is quickly oxidized, and some as "nonfuel" in which the carbon remains unoxidized for very long times.

Keeling (1973) elected to use production data and make estimates of the fraction of the fuel that was ultimately oxidized. At that time fuel accounting for many parts of the world was not sufficiently advanced to provide suitable data sets to account for all the end uses all over the world. Production data have been and are more reliable and consistent from year to year. Using the fuel production numbers to calculate CO_2 emissions can be thought of as metering the man-induced carbon flow from the earth's crust to the atmosphere at the boundary where the carbon crosses the earth's surface.

Use of fuel consumption data might be intellectually more satisfying because it is in the consumption that the CO_2 is produced. However, the consumption data available cover what the UN calls "apparent consumption." The UN obtains apparent consumption by adding a country's excess of imports over exports to its production, and subtracting the amount used in bunkers and for increases in stocks. The amounts of consumption as tabulated by the UN have been consistently less than the aggregated amounts of production—even when changes in stocks are considered. Much of the difference appears to be in the use of fuel to produce fuel, particularly the use of oil in refineries to produce those products that make up the consumption numbers.

Coal and gas consumption data can easily give a reasonably accurate picture because very little transformation takes place between the raw (mined) fuel and the fuel used by the consumer. The calculation of emissions from inland consumption data for coal and gas is straightforward and gives results that are consistent and nearly identical with those determined from fuel production data. The fact that global imports of each fuel for a given year almost always exceed global exports indicates that "apparent consumption" data includes some accounting difficulty, but the difference is generally about 0.1 percent of production.

Crude petroleum presents a different problem in that almost none of the fuel is consumed as crude. Rotty (1982) attempted to reconcile the world production of crude petroleum and natural gas liquids with the consumption of liquid fuels and other petroleum products as tabulated by the UN Statistical Office. The balance he achieved for the liquid fuels account for 1979 is indicated in Table 5. In the same paper, Rotty (1982) calculated the 1979 CO_2 emissions from all of the fossil fuels on both production and consumption bases. When all of the fuel consumption data were considered along with properly corrected CO_2-factors, the calculations for 1979 showed a total of 5191 million tons of carbon as CO_2. For comparative purposes, the calculations based on production data showed a total of 5224 million tons—a difference of 0.6 percent. (Later in this report 5246 million tons of carbon is given as the result for 1979, the difference being a combination of using recently revised UN fuel data and new estimates for (FO) and (C) developed in the following sections.) Clearly, the difference between the result based on fuel consumption data and that based on fuel production data is small in comparison to the probable error in fuel statistics.

Because fuel production and consumption data are so closely linked and because the production data are easier to use and are more reliable as an historic data set, our computations will continue to rely on the fuel production data.

TABLE 5. 1979 WORLD LIQUID FUELS BALANCE SHEET

Production	Amount (10^3 Tons)	Consumption	Amount (10^3 Tons)	
Crude Petroleum Production	3,123,256	Loss of mass in Refineries (Used as fuel?)	112,934	(3.5%)
Gain in commerce of crude (Imports-Exports-Incr. Stocks)	22,567	Energy Products (2,816,763):		
Natural Gas Liquids to Refineries	38,004	Inland Consumption by Nations	2,604,505	(80.3%)
		Bunkers (International)	152,039	(4.7%)
		Increase in Stocks	15,774	(0.5%)
Subtotal, Input to Refineries	(3,183,827)	Loss in Commerce of Products (Exports-Imports)	44,445	(1.4%)
LPG from Natural Gas	60,071	Nonenergy Products (314,270):		
		Rapid Oxidation	118,343	(3.6%)
		Slow or Nonoxidation	195,927	(6.0%)
Total	3,243,898	Total	3,243,967	

From: Rotty (1982) based on data from 1979 Yearbook of World Energy Statistics, UN (1981).

FUEL FRACTION NOT OXIDIZED

As acknowledged in Equation 1, a fraction of the fossil fuel produced each year is not oxidized during time frames of interest here. Part of the unoxidized carbon results from incomplete combustion in burners (resulting in soot and unburned hydrocarbons) and part of it results from diversion of some of the produced "fuel" to nonfuel uses (e.g., use as raw materials for the chemical industries). In this section we derive values for FO_i in Equation 1, the effective fraction of each year's production which is soon oxidized. In both the fuel and the nonfuel cases the hydrocarbons not burned are oxidized in the environment with times varying from very short (weeks or months) to many years. In the aggregate this slow (noncombustion) oxidation could be approximated by an exponential decay law. In such a situation, over long-time scales the amount oxidized each year will equal the amount produced each year as long as the amount produced each year is nearly constant. When the average lifetime of the unoxidized materials is very long or when the amount produced each year is growing, there is a net amount that remains unoxidized. Attempting to estimate production growth rates and decay rates for each unburned or incompletely oxidized hydrocarbon species would become extremely involved. Instead we have aggregated for all liquid fuels and have made subjective estimates of the extent to which production and net oxidation are likely to differ during a given year. Although this is never fully satisfying it is important to recognize that most of the hydrocarbons are oxidized as fuels and that the data cited do provide close bounds for the fractions which are likely not to be oxidized. The probable error introduced through this aggregation and estimation procedure is small in comparison to uncertainties in the fuel production data and more rigorous examination of the noncombustion oxidation rates does not seem justified for the calculation of CO_2 emissions.

Natural Gas Produced but Not Oxidized

As illustrated in Figure 1, most of the natural gas produced in the U.S. is used for fuel. Data required to obtain the nonfuel use of natural gas globally are not available in formal references so we have based our estimates on what data are available for the U.S. Nonfuel gas use in the U.S. is no longer being published by the Department of Energy but we note the mean value for 1970-76 is 3.16 percent of production (Table 6). The lack of markets and infrastructure for using natural gas as a fuel leads to massive flaring at oil fields in some parts of the world and also leads us to expect that the fraction of marketed gas that ends up in nonfuel uses may be significantly larger in those areas than in the U.S. On the other hand, the total world production is still dominated by countries like the U.S., the U.K., Canada, and the Netherlands where gas is largely used as a fuel. Based on the data for the U.S. given in Table 6, we estimate that global nonfuel use of gas is about 3 percent of production. Because the nonfuel use is small, any error in basing the estimate on the biggest producers gives uncertainties that are small fractions of total marketed production. A large fraction of the nonfuel gas goes to ammonia production during which the carbon in the gas is mostly oxidized; the remainder to uses in which the carbon will be oxidized at varying rates over a period of years. The total quantity for nonfuel use has been increasing with time and, in accord with the principle that slowly oxidizing material decays exponentially with time, this suggests that a small amount of unoxidized gas accumulates each year. As a result of increasing nonfuel use and the production of long-lifetime products, we assume that, over time, an amount of carbon equivalent to two-thirds of the carbon in each year's nonfuel-use gas is oxidized during that year. Because nonfuel use is 3 percent of production, this is the same as assuming that, on the average, 1 percent of each year's produced gas remains unoxidized for long periods as a result of nonfuel uses.

Because of incomplete combustion, a small amount of the carbon in the gas used as a fuel will not be oxidized and will remain as soot either around the burner, in the stack, or in the environment. Although the amount of unoxidized carbon is impossible to determine on a global scale, it is extremely small in modern combustion systems and we use, as an upper limit, that 1 percent of the carbon in gas produced globally remains unoxidized during combustion processes.

For natural gas the fraction of annual production remaining unoxidized each year is thus taken to be 0.02, i.e. 0.01 for unoxidized nonfuel uses and 0.01 for unoxidized carbon in combustion. The sequence of assumptions

TABLE 6. NONFUEL USE OF U.S. NATURAL GAS (10^6 cubic meters)			
Year	Gas Production	Nonfuel Use	Nonfuel as % of Production
1976	540,599	17,415	3.22
1975	545,124	16,819	3.09
1974	580,788	20,109	3.46
1973	615,784	19,813	3.22
1972	618,768	18,518	2.99
1971	618,582	18,369	2.97
1970	601,309	18,856	3.14
1970-76 average			3.16

Gas production data from 1979 Yearbook of World Energy Statistics, UN (1981). (Heating value of U.S. natural gas of 38,017 Kjoules/m^3.) Nonfuel use is from API (1977).

here imposes an uncertainty on the gas oxidized of about one percent of the gas produced. Thus the fraction of gas oxidized is $FO_g = 0.98 \pm 0.01$.

Liquids Produced but Not Oxidized

A key question for CO_2 production from crude oil and natural gas liquids is the fraction of production which is burned or otherwise oxidized on a short time scale as opposed to that which ends up in e.g., fibers, lubricants, or paving materials, and is oxidized only over a longer interval.

The United Nations statistics separate refinery output into energy products (aviation gasoline, motor gasoline, jet fuel, kerosene, gas-diesel oil, residual fuel oil, LPG, and refinery gas) and nonenergy products (naphthas, white spirits, lubricants, bitumen (asphalt), petroleum waxes, petroleum coke, and others) with the nonenergy products comprising 10.2 percent of the total in 1979. United Nations data also distinguish the components of natural gas liquids (natural gasoline, condensate, LPG, and "other natural gas liquids"). With the exception of some of the LPG, most of the natural gas liquids are consumed as fuels.

Turning again to United States data for guidance, we find in Figure 2 that about 12 percent of U.S. refinery output in 1981 is "other" products. Table 7 subdivides this "other" category and allows identification of petroleum fractions which are used in ways that do not lead to immediate oxidation. In addition, a major fraction of the liquified petroleum gases and ethane in Figure 2 may not undergo prompt oxidation. The total remaining unoxidized depends to a large degree on both the amounts used in the petrochemical industry and the way in which those products are used. Without a belabored analysis of the world petrochemical industry, we use U.S. data as an analog in making estimates of unoxidized carbon from UN data. Starting with the UN tabulations for refinery nonenergy products and the LPG and ethane from gas liquids plants, we estimate the fraction that is likely to remain unoxidized for long periods of time.

Most of the LPG from refineries is probably consumed as fuel and the UN lists LPG as an energy product from refineries. Therefore, we estimate the amount of LPG and ethane that is used in the petrochemical industry as a

TABLE 7. 1981 U.S. REFINERY OUTPUT OF "OTHER" PRODUCTS
(See Figure 2)
(10^3 bbl)

Natural Gasoline	42,363
Unfractionated Stream	182
Aviation Gasoline	11,147
Petrochemical Feedstocks	208,861
Special Naphthas	27,018
Lubricants	55,958
Wax	6,581
Coke	91,868
Asphalt	123,982
Road Oil	760
Still Gas for Fuel	206,339
Miscellaneous Products	36,213
DOE Reclassification (Adjustment)	-98,214
	713,118

From: U.S. Department of Energy (1982b), DOE/EIA-0340(81)/1.

fraction of only the LPG and ethane produced in natural gas liquids plants. This does not imply that all the LPG used in the petrochemical industry comes from gas processing plants, but only that the global quantity can be best estimated as a fraction of the LPG produced in gas processing plants. In the U.S., the 232.76 million barrels of LPG and ethane sold for chemical and industrial uses in 1931 represents 50.7 percent of that produced in gas processing plants. The industrial sales include use as a standby fuel, in space heating, flame cutting, metallurgical furnaces, and plumber's torches. They also include sales for use as refinery fuel. Chemical use includes those gases employed as raw materials, solvents, and in the production of synthetic rubber. Data for 1981 are not available, but in 1979 the split was 80 percent to chemical use and 20 percent to industrial fuel use. Thus, the equivalent of (0.8)(50.7) = 40.6 percent of the LPG and ethane produced in U.S. natural gas liquids plants is used in applications in which oxidation occurs very slowly. Because the petrochemical industry outside the U.S. depends more heavily on feedstocks from refineries, especially certain napthas, we estimate that, on a worldwide basis, about 40 percent of the LPG and ethane produced from natural gas processing plants ends up in materials which are not soon oxidized.

In the United Nations tabulation of nonenergy refinery products, what is defined as napthas is largely used as chemical feedstocks, and nearly half of the petrochemical feedstocks in Table 7 is naptha. This is a major feedstock to the western Europe petrochemical industry and we estimate that about 80 percent of the napthas produced globally remain unoxidized for long times in plastics, tires, and fabrics.

A substantial part of the nonenergy refinery products is asphalt. Even when paved roads, parking areas, and roofs deteriorate or are removed, most of the asphalt remains in an unoxidized state. Thus, assuming that virtually all of the UN reported asphalt production from petroleum refineries remains unoxidized for long periods introduces a small overestimation. Petroleum waxes are used in manufacture of candles, polishes and waterproofing of containers, wrappings, etc. White spirits are used as paint solvents and as dry cleaning materials. Petroleum coke is mostly used in metallurgical processes and the fraction of the carbon that remains unoxidized is probably small. We estimate these nonenergy products except asphalt are mostly oxidized rather promptly and that assuming full oxidation introduces small error of opposite sign from assuming that all asphalt is not oxidized.

The UN category of lubricants gives us a problem because a non-negligible part of lubricating oil is oxidized in use. Spillage and oil drained from engines are frequently flushed into other waste liquid streams or disposed of in absorbants or containers in land fills. We have used the estimate that approximately 50 percent of lubricants produced by petroleum refineries remain unoxidized for long periods of time.

Our assumption is that, allowing for errors of both inclusion and omission, the quantity of liquid fuels not oxidized each year is approximated by the sum of 40 percent of the LPG and ethane from gas liquid plants, 80 percent of the napthas from petroleum refineries, all of the asphalt, and 50 percent of the lubricants. This is summarized in Table 8. The conclusion is that 6.5 to 6.9 percent of petroleum liquids is not soon oxidized and we adopt 6.7 percent for our computations. For comparison Hatch and Matar (1977a) reported that in 1974 6.5 percent of world crude went into petrochemicals. Also, Flavin (1980) estimated that 1979 production of synthetic materials amounted to 10 million tons of synthetic rubber, 10 million tons of synthetic fiber, and 60 million tons of plastic. The sum of the unoxidized LPG, ethane and napthas in Table 8 is 93.5 million tons. Our analysis suggests it is unlikely the true value of unoxidized liquids is greater than 8.7 percent or less than 4.7 percent of annual production.

Having based this analysis on data for the last decade, there remains the question of changes in the unoxidized fraction during earlier decades in the 1950-1981 period. United Nations data on nonenergy products from refineries for 1970-1980 published in the 1979 and 1980 Yearbooks of World Energy Statistics differ markedly from those published in 1976, the most recent figures being, on average, a factor of 1.33 larger for the 5 years of overlap. Thus, we assume that data for nonenergy products before 1970 are subject to sizable revision and a better estimate of nonoxidative uses can be obtained by applying a 1971-1980 average to the crude production uniformly rather than trying to itemize nonenergy uses. API (1975) data also suggest that the time dependent bias implicit in carrying a constant fraction back to 1950 is small. Lacking better information, we shall use the 6.7 percent factor for the entire 1950-1981 period.

TABLE 8. ESTIMATE OF WORLD PETROLEUM LIQUIDS PRODUCED BUT NOT OXIDIZED EACH YEAR (10^3 tons)

	40% of LPG & Ethane from Gas Plants	80% of Naptha	Asphalt	50% of Lubricants	Total	% of Liquids Produced
1980	25,754	58,541	97,941	19,649	201,885	6.53
1979	25,989	67,500	101,508	19,700	214,697	6.63
1978	23,382	66,025	97,760	18,448	205,615	6.62
1977	23,169	66,412	91,372	17,560	198,513	6.45
1976	22,196	65,853	85,904	16,543	190,496	6.44
1975	21,864	56,194	85,722	15,578	179,358	6.57
1974	21,809	70,862	88,141	17,196	198,008	6.88
1973	21,232	70,581	90,048	16,489	198,350	6.92
1972	20,178	60,749	83,568	15,201	179,696	6.83
1971	18,477	55,382	80,415	14,819	169,093	6.79
						av. 6.67

1976-1980 data from 1980 Yearbook of World Energy Statistics, UN (1982).
1971-1975 data from 1979 Yearbook of World Energy Statistics, UN (1981).

The other situation for which we should make some adjustment in the CO_2 computation is the failure to achieve 100 percent combustion of fuels actually delivered to burners. Carbonaceous materials that are discharged not completely oxidized include those, like CO, which undergo complete oxidation fairly promptly in the environment; others, like soot, which do not oxidize in times of interest; and others, like methane, which oxidize in the environment at a rate such that some finite fraction is oxidized in the first and each succeeding year of interest. For this third class of compounds any difference between the total amount of carbon being oxidized in a given year and an estimate thereof based on full oxidization of current year discharge must be a consequence of an increase in production rate. The simple assumption of an equivalent fraction of material not oxidized during a current year will not introduce significant error so long as the total fraction of material in this class is small.

To estimate the fraction of liquid fuel which goes to burners but is not fully oxidized, we used Environmental Protection Agency estimates of nationwide pollutant emissions in the U.S. In 1976, U.S. emissions of hydrocarbons to the atmosphere amounted to 27.9×10^6 tons, of which 14.7×10^6 tons were related to transportation and oil and gas refining, production, and marketing (Table 9). Another 1.4×10^6 tons were from stationary fuel combustion sources. Of the 13.4×10^6 tons of total suspended particulates discharged to the atmosphere, 1.3×10^6 were from transportation and petroleum refining with another 4.6×10^6 from stationary fuel combustion sources. Table 9 lists emissions from many sources, but we are concerned here only with those associated with combustion of liquid fossil fuels, having already discounted quantities for nonfuel uses such as organic solvents.

In these calculations we assume that half of the hydrocarbons and one-fourth of suspended solids from stationary fuel combustion represent carbonaceous materials attributable to burning liquid fuels, the remainder from other fuels. Then, for the United States, 15.4×10^6 tons of hydrocarbons and 2.5×10^6 tons of suspended carbonaceous particulate material represent incompletely oxidized liquid fuels from combustion applications. If this material undergoes oxidation in the environment over time (some of it very slowly), we can consider that some fraction of 17.9×10^6 tons represents the portion of the 1976 U.S. liquid fuel consumption which should not be counted as CO_2 production.

TABLE 9. 1976 U.S. EMISSION OF HYDROCARBONS AND
TOTAL SUSPENDED PARTICULATES*
(10^6 tons/year)

Source Category	TSP	HC
Transportation	1.2	10.8
Highway Vehicles	0.8	9.3
Nonhighway Vehicles	0.4	1.5
Stationary Fuel Combustion	4.6	1.4
Electric Utilities	3.2	0.1
Industrial	1.1	1.2
Residential, Commercial and Institutional	0.3	0.1
Industrial Processes	6.3	9.4
Chemicals	0.3	1.6
Petroleum Refining	0.1	0.9
Metals	1.3	0.2
Mineral Products	3.2	0
Oil and Gas Production Marketing	0	3.0
Industrial Organic Solvent Use	0	2.9
Other Processes	1.4	0.8
Solid Waste	0.4	0.8
Miscellaneous	0.9	5.5
Forest Wildfires and Managed Burning	0.6	0.8
Agricultural Burning	0.1	0.1
Coal Refuse Burning	0.1	0.1
Structural Fires	0.1	0
Miscellaneous Organic Solvent Use	0	4.5

* From: U.S. Environmental Protection Agency (1977).

Many of the hydrocarbons emitted, especially from engine exhausts, are partially oxidized and hence highly reactive (NRC, 1979). Data on selected urban aerosols suggest that the aerosols are on the order of 20 percent carbon and that 30-40 percent of this carbon is graphitic soot and the remainder primary and secondary organic material (NRC, 1979). The total, 17.9 x 10^6 tons, represents about 2.4 percent of the 751 x 10^6 tons of liquid fuels consumed in the U.S. in 1976. Because a fraction of the 17.9 x 10^6 tons is oxidized in the environment in a realtively short time, something approximating 1.5 ± 1 percent of the liquid fuel that goes to burners each year remains in the environment unoxidized.

The U.S. data can only provide a useful approximation of the extent of unburned material globally. The amount unburned is clearly a small fraction of the total and we note that U.S. emissions of some materials have declined in recent years because of technological improvements. Our procedure probably gives low estimates of global emissions of unburned carbon (and hence high CO_2 estimates). In addition, the assumption of a constant 1.5 percent for the unburned fuel introduces some time-dependent bias in the estimate.

The total mass of liquid fuels lost directly to the environment is not large in comparison to the amount produced. Oil spills at sea amounted to 237,600 tons in 1978 (UN Environment Programme, 1979) and there are smaller but much more numerous losses thoughout the processing/delivery system. Loss of organic compounds as liquid effluent at an oil-fired power plant is estimated to be on the order of 15 percent of the airborne hydrocarbons (UN Environment Programme, 1979). None of these is large enough to make a significant correction to the calculations already detailed.

In summary, about 6.7 ± 2 percent of the liquids produced end up in petrochemical applications where they are not soon oxidized and another equivalent fraction of 1.5 ±1 percent passes through burners and is deposited in the environment without being oxidized. We believe the factor for oxidation of liquid fuel produced is $FO_l = (1 - 0.082) = 0.918 \pm 0.03$.

Solid Fuels Produced but Not Oxidized

Incomplete combustion results in the discharge from boilers of coal dust, gaseous hydrocarbons, and unburned char. The concentration of carbon monoxide (CO) in flue gas can be used as a first order indicator of the completeness of the combustion process and data on CO emissions collected by the U.S. National Air Pollution Control Administration (1970) show that emission factors depend strongly on the type and size of the coal-burning unit. Carbon monoxide emissions per unit of energy can be two orders of magnitude larger from small and/or less efficient units than from large, modern pulverized-coal boilers. Any attempt at a general, time-independent factor to compensate for incomplete combustion must recognize that, for example, 82 percent of the U.S. coal consumed in 1981 was burned in utility boilers while only 17 percent was so burned in 1949 (Figure 3). Transportation accounted for 15 percent of U.S. consumption in 1949 and virtually none in 1981. Employing a constant for the unburned fuel fraction for both current U.S. electric utility boilers and steam locomotives is, of course, only marginally justifiable, and then only because the total fuel used in locomotives (in 1949, for example) was on the order of one-tenth of present solid fuel use.

The United Nations Environment Programme (1979) has estimated that of 3×10^6 tons of coal burned in a 1000 MW(e) power plant, 860 tons of carbon end up in CO, 3000 tons as particulates, and about 400 tons in unburned hydrocarbons. If we assume, as a first approximation, that the CO and unburned hydrocarbons are soon fully oxidized in the environment (Chameides and Davis [1982] show the lifetimes of CO and methane in the atmosphere as about 65 days and 7 years, respectively) while the particulate matter remains largely unoxidized, the unoxidized fraction will amount to only 0.14 percent of the carbon. By contrast, Harding (1920) has written "probably the worst fuel loss that a locomotive fireman has to contend with is that which occurs through the escape of unburned fine coal. When the percentage of fine coal is very high, this loss may amount to one-quarter or even one-third of the coal fired," and "even at best there is considerable fuel loss through soot."

Block and Dams (1976) compared the composition of fly ash from an industrial boiler (24-hour capacity of 14 tons of coal) with that of a small home furnace in Belgium (24-hour capacity of 24 kg of coal). The concentrations of inorganic components in fly ash from the home furnace were 2-10 times smaller than in the industrial boiler, apparently due to dilution with

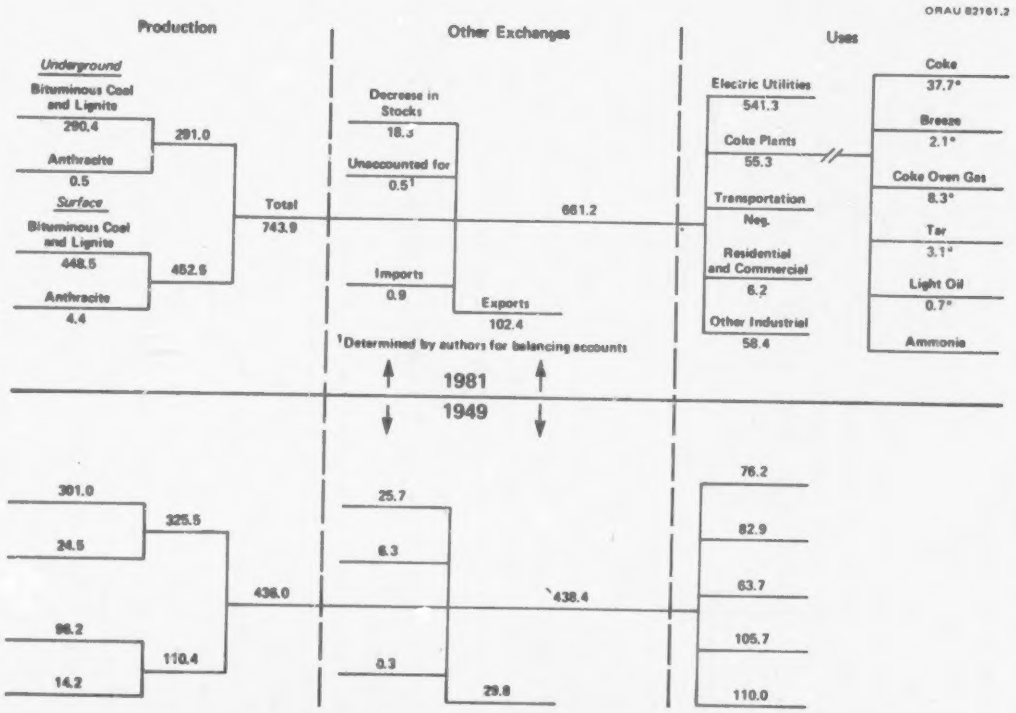
ORAU 82161.2
Production
Other Exchanges
Uses
Underground
Bituminous Coal and Lignite
290.4
Anthracite
0.5
Surface
Bituminous Coal and Lignite
448.5
Anthracite
4.4
291.0
452.9
Total
743.9
Decrease in Stocks
18.3
Unaccounted for
0.5¹
Imports
0.9
Exports
102.4
661.2
¹Determined by authors for balancing accounts
Electric Utilities
541.3
Coke Plants
55.3
Transportation
Neg.
Residential and Commercial
6.2
Other Industrial
58.4
Coke
37.7*
Breeze
2.1*
Coke Oven Gas
8.3*
Tar
3.1*
Light Oil
0.7*
Ammonia
1981
1949
301.0
24.5
325.5
98.2
14.2
110.4
436.0
25.7
6.3
0.3
29.8
438.4
76.2
82.9
63.7
105.7
110.0

Figure 3. U.S. Flows of Coal in 1981 and 1949 (in millions of metric tons)
Data from *Coal Data: A Reference*, DOE/EIA-0064(82), (1982c); and *Coke and Coal Chemicals in 1980*, DOE/EIA 120(80), (1982d).

*The most recent data available for coke plant products are for 1980 when 60.5 million metric tons of coal were consumed by coke plants. Data are in coal equivalents with both data and heating values taken from *Coke and Coal Chemicals in 1980*. Coke converted to coal equivalents at 0.9 from UN, 1981.

large emissions of unburned material. Unburned material comprised about 35 percent of the fly ash from the home furnace.

Another useful perspective can be obtained by examining data from current large coal consumers. Data on combustion efficiency at the Tennessee Valley Authority's Bull Run Steam Plant show that 1 percent of the stack ash is combustible matter; for the Shawnee Plant 5 percent is more typical, and during a recent period of poor performance the Widows Creek Plant ran between 9 and 20 percent combustible matter in the fly ash. Because these plants operate on pulverized coal with about 80 percent of the ash being collected by the stack precipitators, this is probably representative of the average fraction of unburned coal. Taking a representative value of mean ash content for the coal of about 12 percent, between 0.14 and 2.7 percent of the combustible fraction of the coal remains unburned. Typical values are near 0.7 percent and the lower limit is similar to the UNEP number cited above. The Belgian home mentioned above was burning anthracite with 3.1 percent ash, implying that 1.1 percent of the coal was discharged unburned.

With this information it seems reasonable to assume that about 1 ± 1 percent of the carbon in coal currently supplied to furnaces is discharged unoxidized. Using this fraction over the full 1950-present interval probably introduces a time-dependent bias because the number has almost certainly been decreasing with time.

The other adjustment for unburned coal has to do with coal which is used for nonfuel purposes. Figure 3 shows the flow of U.S. coal from the mine to the sectors in which it is ultimately consumed and allows identification of the principal portion which is not used as a fuel. Of coal which is used for coking, two by-products form the bases for a very large chemical industry--the crude light oil and crude tar of Figure 3. The quantities of light oil and tar shown in the figure are given in coal equivalents by heating value. Of the coal tar fraction, some 21 percent is typically used for fuel while benzene (21 percent), creosote oil (20 percent), and road tars (17 percent) are the other principal products (Wainwright, 1977). Benzene, toluene, and xylene typically account for 75 percent of the crude light oil.

Thus it appears that about 75 percent of the coal equivalents which are accounted for as light oil and tar represent the coal which ends up in applications where oxidation is long delayed. From U.S. data, Table 10

TABLE 10. LIGHT OIL AND TAR PRODUCED FROM COAL IN U.S. COKE PLANTS
(in millions of tons coal equivalent by heating value)

Year	Crude Light Oil and Crude Tar	Coal to Coke Plants	% Coal Converted to Light Oil and Tar
1980	3.630	60.510	6.00
1979	4.014	69.944	5.74
1978	3.677	64.773	5.68
1977	4.034	70.488	5.72
1976	4.363	76.838	5.68
1975	4.398	75.840	5.80
1974	4.676	81.828	5.71
1973	5.013	85.366	5.87
1972	5.037	79.560	6.33
1971	4.612	75.477	6.11
1970	5.251	87.543	6.00
1969	5.363	84.731	6.33
		12-year Mean	5.91

From: U.S. Department of Energy (1982c, 1982d) and U.S. Bureau of Mines (1973).

shows that on average 5.91 percent of the coal going to coke plants ends up as light oil and crude tar, and 75 percent of that, or 4.4 percent has oxidation long delayed. Using this number and statistics for world coke, we can estimate the fraction of the global coal production that does not enter the CO_2 route. This calculation of the mass of U.S. nonfuel coal use agrees within 5 percent with the numbers compiled by Dupree and West (1972).

There are three other considerations associated with coal production that could affect CO_2 releases. These are burning of wasted coal on abandoned mine lands, methane ventilated from coal mines, and the use of SO_2 scrubbers at coal-burning plants.

Chaiken (1980) cites a 1968 U.S. Bureau of Mines survey that found 292 waste banks on fire and in a 1977 survey 261 coal deposits in the U.S. were classified as burning. The 292 waste banks contained an estimated 49 million tons of coal. Even if all of this coal was burned over a ten-year period it would still amount to less than 1 percent of U.S. coal consumption. Although it is difficult to estimate tonnages involved, burning in coal deposits is probably no greater than burning on waste piles. The U.S. Environmental Protection Agency (1977) has estimated that coal refuse burning contributes 0.3 percent of U.S. carbon monoxide emissions, but because refuse burning occurs in an oxygen-deficient environment, the contribution to carbon monoxide discharge should be a much larger fraction than the contribution to carbon dioxide discharge. Thus much less than 0.3 percent of the CO_2 emissions can be attributed to this source, and ignoring this as a source of CO_2 seems to be justified.

In considering methane ventilated from coal mines, the content of gas in coalbeds varies considerably but Science Applications, Inc. (1980) estimates an average of 6.25 cubic meters per ton in bituminous coal and anthracite, 2.5 cubic meters per ton in subbituminous coal, and 1.25 cubic meters per ton in lignite. Coal mined in the U.S. in 1979 was composed of 622 million tons of bituminous coal, 109 million tons of subbituminous, 43 million tons of lignite, and 4 million tons of anthracite (U.S. DOE, 1981). The ratio among the four types is .799/.140/.055/.006 (although this has been changing in recent years with increasing amounts of lower grade coal being used) and using methane emission rates of 6.25/2.50/1.25/6.25 cubic meters per ton respectively, the total methane emissions from U.S. coal mined in 1979 were (at an average of 5.45 m^3/ton) 4.24 x $10^9 m^3$. Fully oxidized, this would produce 2.16 x 10^{12}g C as CO_2. Again this number is a very small fraction of a percent of the emissions from coal burning and will be ignored.

The use of SO_2 scrubbing at coal burning plants is still at a sufficiently small scale that it too can be safely ignored as a source of CO_2 to the atmosphere. Coal with 1.5 percent S and 7,000 cal/gm (12,6000 Btu/lb) would discharge 2.381 lb SO_2 per million Btu (1.025 Kg/Kjoule). If SO_2 emissions were limited to the current 0.6 lb SO_2 per million Btu, scrubbing would have to collect 1.781 lb SO_2 per million Btu or 0.0112 tons S per ton of coal. Approximating the SO_2 scrubbing reaction as a stoichiometric exchange of C for S in the gas phase means that the collection of 0.0112 tons S would release 12/32 (0.0112) = 0.0042 tons of carbon per ton of coal. Widespread use of SO_2 scrubbing in the future could result in a small but measurable increase in the CO_2 emission rate.

The conclusion at this point is that from the total mass of coal mined (in tons coal equivalent on a 7,000 cal/g basis) we will subtract 4.4 percent of the mass which goes to coke plants (about 0.8 percent of the coal mined) to accommodate long-term nonoxidative uses, and subtract 1 percent of the remainder to accommodate the fraction which passes through furnaces without being oxidized. Our factor for oxidized fraction of world solid fuel production is thus $FO_s = (1 - 0.008)(1 - 0.01) = 0.982 \pm 0.02$.

CARBON CONTENT OF FUELS

The remaining component required to calculate CO_2 emissions is the global average carbon content of each fuel group (C_i in Equation 1). Because carbon content is correlated with heating value, and because the UN tabulation of gases is in terajoules and of solids in tons of coal equivalent at 7000 calories per gram, the resulting calculations are straightforward.

Gases

Although there are compositional data available for many individual natural gases, we have been unable to locate any statistical summary of the composition of natural gases produced over large geographic areas. From the analytical data for 252 wellhead samples of wet gas from 17 states as analyzed by the U.S. Bureau of Mines in 1976 (Moore, 1977), we eliminated those few samples least likely to be produced as fuels or indicating contamination (i.e., those with heating values less than 8010 kcal/m^3 [900 Btu/SCF] or oxygen concentrations greater than 0.2 percent). For the remaining data, a mean composition was calculated for samples from each state having data available; then these state means were weighted according to the marketed production for that state and a "weighted mean" for the United States as a whole was calculated (Table 11, column 1). This we call the 1976 U.S. reference gas. For comparison a similar "weighted mean" from the 373 samples analyzed in 1970 (Cardwell and Benton, 1971) was calculated and, using their 1970 data, simple unweighted national means and standard deviations were tabulated (Table 11, columns 2, 3, and 4).

Similarly, 174 non-U.S. samples from 18 countries were used to calculate individual country means; data from these 18 countries were combined with the U.S. data by weighting each according to 1970 production statistics to produce a world mean composition (Table 11, column 5)(data from Moore, 1976). This aggregation includes countries which represent 75 percent of the world production but does not include the USSR.

The 1976 U.S. reference gas composition (Table 11, column 1) should closely describe natural gas reported by the U.S. Bureau of Mines and U.S.

TABLE 11. COMPOSITION OF NATURAL GAS
(in volume percent)

	1976 U.S. Reference Gas	1970 Weighted U.S. Mean	1970 Unweighted U.S.		(circa 1970) Weighted World Mean	1976 Adjusted Dry Gas
			Mean	Standard Deviation		
Methane	88.32	89.32	86.63	9.63	89.24	92.88
Ethane	4.65	4.66	5.02	3.52	4.52	3.91
Propane	2.12	2.04	2.57	2.56	1.95	0.62
Other Hydrocarbons	1.53	1.56	1.88	—	1.54	—
CO_2	0.92	0.65	0.63	1.11	0.78	—
Other	2.46	2.33	3.26	—	2.42	2.59
Higher Heating Value						
kcal/m^3	9685.60	9723.69	9859.31	1010.85	9680.26	9102.62
(Btu/SCF)	(1088.39)	(1092.66)	(1107.90)	(113.59)	(1087.78)	(1022.87)

Department of Energy, as "marketed production." Marketed production means wet gas and the "extraction loss" shown in the gas flow accounts represents processing to remove liquids which subsequently appear in the accounts as "natural gas liquids." The change in gas composition which occurs during the removal of natural gas liquids results in a reduction of heating value. For dry natural gas delivered to customers in 1976, the American Gas Association (1979) reports 9086 Kcal/m^3. Taking the 1976 reference gas, assuming removal of 20 percent of the ethane, 72 percent of the propane (Hatch and Matar, 1977b), all of the heavier hydrocarbons, and all of the H_2S, CO_2, and H_2O, the resulting gas (Table 11, column 6), has a calculated heating value of 9103 Kcal/m^3. This adjusted "dry gas" should closely resemble the composition of gas delivered to U.S. customers in 1976 and that counted by the UN as gas production. For other years the composition should be closely approximated by using the same wet gas composition and adjusting to the heating value of delivered gas, as published by the American Gas Association (see Table 12). This is done by removing appropriate amounts of "natural gas liquids," ethane and heavier hydrocarbons and recognizing that this removal has become increasingly efficient with time.

The 1976 adjusted dry gas contains 0.550 grams of carbon per liter at 0°C and, with the separated CO_2 included, would discharge 0.555 grams of carbon per liter as CO_2 when completely oxidized. Adjusted to 60°F (15.6°C) the temperature at which U.S. gas volumes are measured, and assuming ideal gas behavior, this amounts to 525.4 gC/m^3 or 57.75 gC/1000 Kcal. Doing similar calculations for the other mean gas compositions, we found that the carbon content per unit of energy could be closely represented by a linear relationship with heating value.

This relationship is expressed by the equation,

$$C_g = 57.357 + 1.459 \times 10^{-3} (\Delta H_H - 8898) \qquad \text{Eq. 2}$$

where C_g is the amount of carbon, (in gC/1000 Kcal), and ΔH_H is the higher heating value of the gas (in Kcal/m^3 at 15.6 °C). Equation 2 shows that the carbon content per unit of energy of the gas is not very sensitive to the heating value of the gas. Even though the heating value of "average" natural gas has changed slightly with time (as shown in Table 12), little information is lost by assuming a time averaged heating value. The 1970-80 world average is 8884 Kcal/m^3 (37,172 Kjoules/m^3). For the following reasons we have adopted the upward rounded value of 8,900 Kcal/m^3:

TABLE 12. MEAN HEATING VALUE OF DRY NATURAL GAS

	U.S.(a) (Kcal/m^3)	World(b) (Kcal/m^3)
1980		8825
1979	9068	8839
1978	9068	8851
1977	9086	8852
1976	9086	8864
1975	9112	8874
1974	9086	8893
1973	9139	8921
1972	9175	8924
1971	9175	8929
1970	9175	8956
1969	9175	
1965-1968	9184	
1964 and before	9211	

NOTES:

(a) From American Gas Association (1979), except 1979 value from U.S. DOE (1980a).

(b) These values are derived by using a representative (constant) heating value of gas from individual countries as reported in the 1980 Yearbook of World Energy Statistics, UN (1982), and calculating a weighted mean, based on annual production statistics. The weighted means are based on the 6 countries that have dominated world gas production over the last decade: U.S., USSR, Netherlands, Canada, UK, and Romania. The decline in the heating value so determined is a consequence of changing fractions of world total being supplied by the U.S.S.R. and Netherlands.

1. Heating values for individual countries are not well known, but the UN reports larger values for most small producers not included in our average,
2. The pre-1970 values were probably higher because U.S. gas made up a larger fraction of the total,
3. The carbon calculation is not very sensitive to small changes in heating value.

The regression equation then gives

$C_g = 57.36$ gC/1000 Kcal.

This is equivalent to Cg = 13.70 tons C/terajoule, and implies that "average" natural gas contains 510 gC per cubic meter. The value for carbon content of gases obtained by this procedure appears to be accurate to within ± 2 percent.

For flared gas there are no data from which to estimate the carbon content directly. Because flared gas is largely associated gas from oil fields it seems unlikely that its heating value is as low as is suggested by the heating value we have used for our global mean gas (heavily affected by Soviet gas). Although some gas is flared without processing, in other cases gas liquids are recovered before flaring. In view of these considerations, the assumption that gas flared globally has a carbon content close to that of dry gas marketed in the U.S. (525 gC/m^3) appears reasonable. Because flared gas almost certainly contains more carbon than the "average" global gas (510 gC/m^3), and gas with more than 540 gC/m^3 would be most unusual, the uncertainty on the assumed value of 525 gC/m^3 (0.525 x 10^3 gC/m^3) is taken to be ± 3 percent.

Liquids

Crude oil is a complex collection of hydrocarbons with about 600 individual hydrocarbons identified to date. The American Petroleum Institute's detailed analysis of Ponca City Crude isolated some 295 hydrocarbons which made up 60 percent of the total crude. "The remaining 40 percent undoubtedly consists of thousands of compounds many of which will never be identified" (Hunt, 1979, p. 34). Petroleum is the raw material for an estimated 7,000 end-use chemicals. Thus the analysis of crude petroleum for CO_2 emissions could be extremely complex.

Variations in petroleum are most often expressed in terms of its specific gravity at 60°F (15°C). The API gravity, where

$$\text{API gravity} = \frac{141.5}{\text{specific gravity}} - 131.5, \qquad \text{Eq. 3}$$

is an indication of the molecular size, carbon/hydrogen ratio, and hence carbon content of a crude oil. Coleman et al. (1978) have assembled analytical data, including API gravity, for 800 important U.S. crudes representing major fields and producing formations. The gravities of this sample varied from 8.9 °API (specific gravity = 1.0078) to 62.9 °API (specific gravity = 0.7279) with a mean of 34.75° API (specific gravity 0.8511) and a standard deviation of 7.71 °API. There is a similar diversity among major world sources of crude and even for the U.S. the mean of 34.75 °API is only indicative because it treats all 800 analyses equally without regard for production rate. According to Carter (1979), the average gravity of world crude varied between 32.0 and 32.9 °API for the years 1970-1979 and might be expected to drop only slightly lower over the next 5 years. Carter shows North American averages between 31.8 and 32.2 for those years.

For converting volume to mass units the U.N. (1982) assumes U.S. crude oil has a specific gravity of 0.848 (35.4 °API). We used U.N. single-country values for specific gravity and took the weighted average value for the 10 largest crude producing countries in 1978 (77 percent of the total). The result was a specific gravity of world crude of 0.857 (33.6 °API). Considering this in combination with Carter's conclusion, world average crude appears to have an API gravity of 32.5° ± 2°.

In Figure 4 we have plotted percent carbon versus API gravity for a few typical North American crudes (Marks, 1978). There is a good correspondence between percent carbon and gravity with 32.5 °API suggesting a composition of about 85.25 percent carbon. Brame and King (1967) give a range of 79.5-87.1 percent carbon for crudes, with a mean of 84.5 percent carbon and Hunt (1979) also lists 84.5 percent as the carbon content of crude oil. The mean carbon content of crude oil will vary slightly from year to year as the

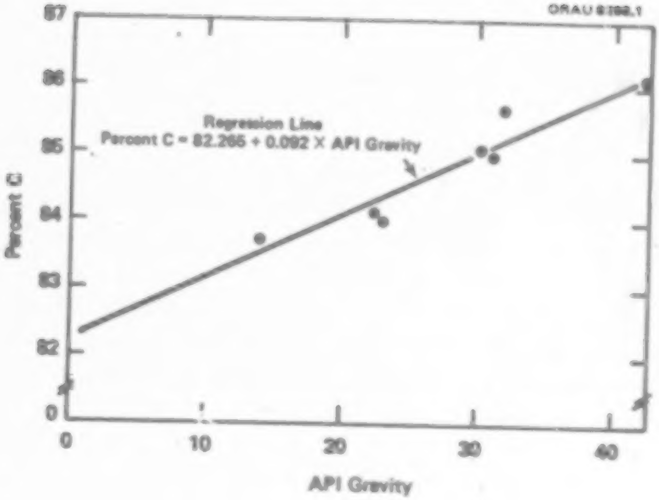

Figure 4. Percent Carbon as a Function of Specific Gravity for Samples Typical of North American Crude Petroleum

distribution of sources changes, and we conclude that $C_1 = 85.0 \pm 1.0$ percent carbon should adequately describe the mean composition of world crude oil during the period of interest here. Because natural gas liquids comprise only 3 percent of the total liquids, little error can be introduced by applying this factor to the sum of crude petroleum and natural gas liquids, as pointed out above.

Solids

As indicated earlier, the UN now attempts to evaluate coals and tabulates production in the energy units "tons coal equivalent" at 7000 cal/gm. The correlation between heating value and carbon content suggests that we can establish estimates for carbon content using the knowledge that the UN has considered the heating value in their published production data. That the correlation between heating value and carbon content is good but not perfect is seen clearly in attempts to write formulas for calculating heating value from chemical analyses. For example, one such attempt arrived at the formula:

$$\Delta H_H = 146.58C + 568.78H + 29.4S - 6.58A - 51.33(O + N) \qquad \text{Eq. 4}$$

where ΔH_H is the higher heating value in Btu/lb and C, H, S, A, and (O+N) are weight percents, respectively, of carbon, hydrogen, total sulfur, ash, and oxygen plus nitrogen by difference (all on a moisture-free basis). While this was the most successful of five published equations which were evaluated by the Institute for Gas Technology (1978), when calculated and measured values for 775 U.S. coals (including lignites and subbituminous coals) were compared, the average of the absolute value of the differences was 93 Btu/lb (52 cal/g). It is clear that whether the precise expression of Equation 4 is used, having the heating value of coal makes it possible to estimate the carbon content.

A higher heating value of 7000 cal/g is a reasonable standard for coal equivalents and until recently it was the standard employed in the UN data tabulations. To determine the factor C_s to be used in Equation 1, it is then necessary to establish the average carbon content of 7000 cal/g coal. Although the carbon content of solid fuels is variable, for 7000 cal/g coal close definition is possible. For the Zubovic et al. (1979) compilation of coal analyses (mean heating value of 7090 cal/g) the arithmetic mean carbon content was 70.9 percent for the 491 samples for which ultimate analyses were available. These were samples with heating values varying from 4706 to 8307 cal/g and carbon content from 48.2 to 85.9 percent. For the 26 samples with heating values between 6900 and 7100 cal/g the mean heating value was 6997 kcal/kg and the mean carbon content 70.7 percent. "Coal equivalent" is thus assumed to contain 70.7 percent carbon. We suggest C_s = 70.7 percent carbon describes coal equivalent within ±2 percent, although it does appear that the carbon fraction per unit heating value increases slightly for low grade coals.

The higher heating value of coal is a commonly measured value and most of the discussion above has been based on higher heating value. However, in its most recent tabulations the UN has attempted to base coal equivalents on lower heating value ("net heat value" in their terminology) while staying with a 7000 cal/g basis. Therefore we must make some adjustment. To use the UN data set for coal production with coal composition information based on the higher heating value, the coal composition factor must include a multiplier which simultaneously converts tons of coal equivalent from a lower to a higher heating value basis. This factor is based on U.S. data and assumes only that the ratio of $\Delta H_H/\Delta H_L$ is the same for average world coal as for U.S. coal. Table 3 shows, by year, the ΔH_H of U.S. coals as reported by the U.S. Bureau of Mines and DOE and the heating value assumed by the UN in converting tons of U.S. coal to tons coal equivalent. By including a factor of $\Delta H_H/\Delta H_L$ in the multiplication we effectively revert to a 7000 cal/g ΔH_H basis, and this can be regarded simply as a heating value adjustment factor. It should be changed if the UN alters its accounting basis in the future.

From the heating values used by the UN in tabulating U.S. coal production in the 1980 Yearbook of World Energy Statistics (Table 3) the mean heating value adjustment factor for 1970-1979 data is found to be 1.055. We assume this factor is appropriate for world coal. Combining the composition and heating value adjustment factors, the effective carbon content of world average coal is found to be C_s = (0.707)(1.055) = 0.746 ± 0.02. We emphasize that this is uniquely appropriate for the UN coal statistics reported on a "net heat value" basis.

CALCULATION OF CO_2 EMISSIONS AND ESTIMATION OF ERROR

The computation of CO_2 emissions from fossil fuel burning is accomplished by multiplying the factors developed above and summarized in Table 13. The fuel data taken from the 1980 Yearbook of World Energy Statistics (UN, 1982) and the calculated values for CO_2 emissions are presented and summed in Table 14. (The 1981 fuel and CO_2 emissions are estimated from incomplete data for that year as compiled in UN quarterly reports.) A large number of assumptions and approximations are embodied in these computations but in every case the values are rather well bounded. We have tried to draw these approximations in such a way as to acknowledge the uncertainties but to show also that the results cannot lead to large errors in the calculation of CO_2 emissions.

Because liquids provide probably the worst case for accumulation of errors, assembling and contemplating all of the errors and approximations contained in the calculation of CO_2 emissions from liquids provides bounds for other fuels as well. Global production data can be used as a surrogate for annual consumption if identifiable nonoxidative uses are subtracted. Changes in stocks are small compared to production and, over a series of years, must contain positive and negative numbers summing to near zero. Assuming that crude oil and natural gas liquids could be summed on a mass basis introduces little error because of the demonstrated small difference in mean carbon content and the small contribution of NGLs to the total. Global fuel production numbers compiled by the United Nations are consistent with numbers published elsewhere and represent the best efforts of a staff dedicated to the sole task of bringing together all of the available information. All production data are subject to revision as additional information becomes available but ultimately all data depend on the reporting of individual nations and production companies. The error estimates for production data (± 8 percent for liquids) are judgments made after discussing global and some individual country data with the UN staff plus discussions with others more familiar with U.S. data.

The most speculative numbers in our computation are those that relate to how crude oil is ultimately used and the rate at which it is oxidized. It is absolutely clear, however, that over 90 percent of crude is used for

TABLE 13. FACTORS AND UNITS FOR CALCULATING ANNUAL CO_2 EMISSIONS FROM GLOBAL FUEL PRODUCTION DATA*

$$CO_{2_i} = (P_i)(FO_i)(C_i)$$

From Natural Gas Production

CO_{2_g} = CO_2 emissions in 10^6 tons C
P_g = Annual production in thousands of 10^{12} joules (± = 10 %)
FO_g = Effective fraction oxidized in year of production = 0.98 ± 1%
C_g = Carbon content in 10^6 tons per thousand 10^{12} joules = 0.0137 ± 2%

From Crude Oil and Natural Gas Liquids Production

CO_{2_l} = CO_2 emissions in 10^6 tons C
P_l = Annual production in 10^6 tons (± = 8%)
FO_l = Effective fraction oxidized in year of production = 0.918 ±3%
C_l = Carbon content in tons C per ton crude oil = 0.85 ±1%

From Coal Production

CO_{2_s} = CO_2 emissions in 10^6 tons C
P_s = Annual production in 10^6 tons coal equivalent (± = 11.2%)
FO_s = Effective fraction oxidized in year of production = 0.982 ± 2%
C_s = Carbon content in tons C per ton coal equivalent = 0.746** ± 2%

From Natural Gas Flaring

CO_{2_f} = CO_2 emissions in 10^6 tons C
P_f = Annual gas flaring in 10^9 cubic meters (± = 20%)
FO_f = Effective fraction oxidized in year of flaring = 1.00 ± 1%
C_f = Carbon content in tons per thousand cubic meters = 0.525 ± 3%

* All masses are in metric tons (10^3kg).

**The 0.746 value includes a heating value adjustment to recognize that the carbon content, developed on a higher heating value basis, must be increased when used with UN production data (UN, 1982) based on "net" or lower heating values.

TABLE 14. CO_2 EMISSIONS FROM FOSSIL FUELS, 1950-1981

Year	Gas Fuel Production[1] (10^{12} joules) (thousands)	CO_2 From Gas Fuel (10^6 T C)	Liquid Fuel Production[2] (10^6 T oil)	CO_2 From Liquid Fuel (10^6 T C)	Solid Fuel Production[3] (10^6 T coal eq)	CO_2 From Solid Fuel (10^6 T C)	Gas Flared & Vented[4] (10^9 m^3)	CO_2 From Flared Gas (10^6 T C)	Total CO_2 From Fossil Fuels (10^6 T C)
1950	7,193	97	542	423	1,468	1,075	44	23	1,618
1951	8,562	115	613	478	1,549	1,135	46	24	1,752
1952	9,241	124	646	504	1,534	1,124	50	26	1,778
1953	9,772	131	684	534	1,542	1,130	51	27	1,822
1954	10,250	137	714	557	1,528	1,119	52	27	1,840
1955	11,140	150	801	625	1,654	1,212	58	30	2,017
1956	12,027	161	870	679	1,743	1,277	61	32	2,149
1957	13,247	178	915	714	1,793	1,314	67	35	2,241
1958	14,296	192	938	732	1,829	1,340	66	35	2,299
1959	15,976	214	1,012	790	1,877	1,375	69	36	2,415
1960	17,501	235	1,089	850	1,946	1,426	75	39	2,550
1961	18,865	253	1,161	906	1,825	1,337	79	41	2,537
1962	20,592	276	1,258	982	1,868	1,368	84	44	2,670
1963	22,364	300	1,351	1,054	1,947	1,426	90	47	2,827
1964	24,447	320	1,458	1,138	2,018	1,478	97	51	2,995
1965	26,172	351	1,563	1,220	2,048	1,500	104	55	3,126
1966	28,313	380	1,696	1,323	2,077	1,522	115	60	3,285
1967	30,500	409	1,822	1,422	1,998	1,464	126	66	3,361
1968	33,130	445	1,988	1,551	2,040	1,494	139	73	3,563
1969	36,268	487	2,139	1,669	2,077	1,522	152	80	3,758
1970	38,441	516	2,350	1,834	2,152	1,576	167	88	4,014
1971	41,204	553	2,492	1,945	2,146	1,572	171	90	4,160
1972	43,391	583	2,632	2,054	2,163	1,585	180	95	4,317
1973	45,284	608	2,868	2,238	2,190	1,604	213	112	4,562
1974	45,897	616	2,877	2,245	2,202	1,613	204	107	4,581
1975	46,246	621	2,730	2,130	2,297	1,683	183	96	4,530
1976	48,043	645	2,958	2,308	2,357	1,727	210	110	4,790
1977	49,275	662	3,077	2,401	2,410	1,765	206	108	4,936
1978	51,525	692	3,107	2,424	2,438	1,786	201	106	5,008
1979	54,339	730	3,236	2,525	2,574	1,886	200	105	5,246
1980	55,096	739	3,093	2,413	2,615	1,916	194	102	5,170
1981[5]	58,118	780	2,878	2,246	2,650	1,941	178	93	5,060

Notes: Table 14

1. Data from 1980 Yearbook of World Energy Statistics, UN (1982), and Data Tape of UN Energy Statistics.

2. Data from 1980 Yearbook of World Energy Statistics, UN (1982), and Data Tape of UN Energy Statistics. Numbers are the sum of crude oil and natural gas liquids, both in mass units.

3. Data from Data Tape of UN Energy Statistics; 0.810 coal equivalency factor used for hard coal produced in Poland (in millions of tons of coal equivalent where coal equivalent means net heating value of 7,000 cal/gram).

4. 1950-70 data from Rotty (1974).
   1971, 1972 data from U.S. Department of Interior (1974).
   1973 data from U.S. Department of Energy (1979).
   1974-1978 data from U.S. Department of Energy (1980b).
   1979-1981 data are estimates by authors.

5. All 1981 production values are estimates based on midyear data.

The data tapes of UN Energy Statistics were employed with the assistance of J. E. Horwedel, Carbon Dioxide Information Center, Oak Ridge National Laboratory.

fuels that are burned within a short time of production and errors of only a few percent of total CO_2 emissions are possible as a result of accounting inadequacies within the fraction remaining unoxidized. The fraction not oxidized results from both nonfuel use and combustion inefficiencies. The assumption of 98.5 ± 1 percent oxidization effectively recognizes that CO and most unburned or partially oxidized hydrocarbons will soon be oxidized in the environment while soot will remain unoxidized for long periods of time. Although recognizing that we have committed errors of both omission and inclusion, we have listed a variety of nonfuel petroleum products that have long lifetimes before oxidation, and have assumed that the sum closely approximates the fraction of petroleum which is not oxidized each year. Recent year data suggest this is about 6.7 percent of production and we conclude that errors of greater than ± 2 percent of production are unlikely. One problem is that this fraction (and the combustion efficiency) are functions of time and place and we are forced to rely on recent U.S. data to infer long-term global averages. If the fraction of fuel going into long-lifetime products has been increasing over the last several decades, use of estimates of that fraction based on present data will result in CO_2 emissions that are slightly too low for earlier years. However this will be, at least partially, compensated by an increase in fuel combustion efficiency with time. The data cited above also suggest that nonfuel uses of coal and natural gas have been decreasing with time while average coal combustion efficiency has been increasing with time. Data are not available to try to discern quantitatively the effect of changing nonfuel uses and increasing combustion efficiencies on the growth rate of CO_2 emissions.

There are enough data published on the composition of world crudes, partly because so much of world crude enters into international commerce, that we can be quite confident in establishing its mean carbon content. Errors in the procedures and the calculations stemming from carbon content or from fracion oxidized are much smaller than those from fuel data.

With present global fuel data, error limits cannot be assigned with scientific precision, but rather the ± values indicated represent our subjective judgment for an approximate 90 percent confidence interval over distributions not unlike normal. This is distorted somewhat when we recognize that some of the factors used are dominated by data from the most recent third of the data sequence and that time dependent biases have been introduced by employing constant multipliers for the entire 1950-1981 period. Working largely in energy units should suppress time-dependent, systematic errors in the fuel production and fuel composition data, but fuel combustion efficiency and nonfuel use have almost certainly undergone systematic changes not recognized in our calculation. Since these changes affect quantities which are of the order of a few percent and the quantities are then subtracted from unity, any adjustments can give only small changes in net CO_2 production or its rate of increase.

We have estimated the overall uncertainty associated with CO_2 emissions by the analysis depicted in Table 15. In 1980 the CO_2 emissions from each fuel group were divided as follows: 14 percent from natural gas, 47 percent from liquid fuels, 37 percent from solid fuels, and 2 percent from flaring gas. Using these percentages as weighting factors on the uncertainties for each fuel group, this analysis suggests that the estimates on the global total emissions of CO_2 from fossil fuels presented in Table 14 have an uncertainty of between 6 and 10 percent, depending on how one chooses to aggregate the uncertainties.

The uncertainty in the value used for fuel produced is independent of the uncertainty in the estimate for fraction oxidized and the estimated carbon content. The uncertainty in the product of the three terms is estimated by the square root of the sum of the squares of the uncertainty in each individual component. However, in summing the uncertainties for CO_2 emissions from each fuel type to obtain an overall uncertainty for global CO_2 emissions independence is not assured. If the data for each fuel type were totally independent, the square-root-of-the-sum-of-the-squares would be the appropriate procedure and the estimated uncertainty would be 6.06 percent. In at least a few cases, it is likely that data for gases, liquids and/or solids are developed and tabulated in the same office or even by the same individual and errors of the same type may occur in data for more than one fuel type. In this case compensating errors would not occur and the cumulative uncertainty could be as much as $\sum f_i \sqrt{\Sigma E_j^2}$, 10.16 percent in this case (see Table 15). The estimated uncertainty in the final emission numbers of between 6 and 10 percent is based on a 90 percent confidence interval.

TABLE 15. UNCERTAINTIES IN CO_2 EMISSIONS (%)

	E_1 Fuel Produced (P)	E_2 Fraction Oxidized (FO)	E_3 Carbon Content (C)	Emissions* $\sqrt{\Sigma E_j^2}$	Weighted** Emissions $f_i \sqrt{\Sigma E_j^2}$
Gases	10	1	2	10.25	1.47
Liquids	8	3	1	8.60	4.01
Solids	11.2	2	2	11.55	4.28
Gas Flared	20	1	3	20.25	0.41
Total Uncertainty:	a. If uncertainties for the individual fuels are mutually independent.			$[\sum(f_i \sqrt{\Sigma E_j^2})^2]$	= 6.06
	b. If uncertainties for the individual fuels are not independent.			$\sum f_i \sqrt{\Sigma E_j^2}$	= 10.16

* E_j is the uncertainty in the factors P, FO, and C for a given fuel type i.

** Weighted by 1980 weighting factor f_i = 1980 emissions from i th fuel type divided by total 1980 emissions.

The uncertainty of 6 to 10 percent is applicable to CO_2 emissions for a given year, but the uncertainty in the relative change from year to year is a different problem. Growth rates are determined by linear least squares fitting of the logarithms of the annual emissions and thus confidence in growth rates can be different from confidence in annual values. There is a memory component in the annual fuel data; that is, fuel production data for a given year are influenced by, and hence not totally independent of, the previous year's data. One of the checks employed by the UN is that reported production data must demonstrate continuity with the previous year's values. In addition, some time-dependent bias may be introduced by the calculative procedure used. However, if we assume that there is a constant exponential growth in CO_2 emissions for a particular period, then we can use some simple statistics to estimate confidence limits on the annual growth rate. Assuming that the yearly emissions are independent, and that the statistical deviation from constant exponential growth is the same as the statistical deviation in the individual annual emissions, and that ± 8 percent is the 90 percent confidence bound on individual values we calculate that the annual growth rate for the period 1950-1973 is 4.46 ± 0.24 percent. For the period 1973-1981 it is 1.86 ± 1.13 percent.

Because of the memory in the data system, data precision can be much greater than data accuracy; the uncertainty in individual values is not reflected in the difference between successive annual values. Thus, in determining year to year differences, using annual values calculated to four significant figures is not inappropriate.

To reduce the uncertainty in the final result would require that the reliability (or confidence in) the fuel production data be substantially improved. It is shown clearly in Table 15 that most of the uncertainty in calculating CO_2 emissions from fossil fuels comes directly from this source. Developing improved confidence in the UN fuel statistics for even that small group of countries that produce most of the world's fuel, would require a major effort.

We have made no attempt to examine CO_2 emissions prior to 1950. Estimates of Keeling (1973) remain the only source extending back to 1860. There is virtually no difference between the results presented here for the early 1950's and Keeling's values for the same period (e.g., 1618 x 10^6 tons

C for 1950 calculated here compares with 1613 x 10^6 tons carbon calculated by Keeling). Although this apparent agreement makes it easy to combine data for the two periods into a single sequence, we caution that the two series have been developed by different methods from data sets having different uncertainties.

The only other significant contribution of CO_2 emissions from industrial activities appears to be related to cement manufacture. Cement production contributes about 2 percent additional to the total CO_2 emissions. Cement data have not been reexamined here and for a complete data set of industrial CO_2 releases, cement data from Rotty (1982) should be added to the fossil fuel data derived here.

CONCLUSIONS

An important outcome of this exercise is that an independent examination of the full computation of CO_2 emissions from fossil fuels has been completed and no fundamental oversights in the earlier methods of Keeling and of Rotty have been found. Differences from the earlier results are minor, well within the uncertainty limits in the data available. At the same time we emphasize the uncertainties in the results, and any effort toward a global carbon balance should acknowledge that CO_2 production numbers reported to three or four significant figures are nonetheless subject to substantial uncertainty.

The CO_2 emissions given in Table 14 are displayed in Figures 5 and 6. Figure 5 shows graphically the rate at which CO_2 emissions have been growing and the relative contributions of the various fuels. This figure shows the early dominance of the emissions from coal and the rapid increase in emissions from liquids between 1950 and the early 1970s. The disruption of the growth in emissions that accompanied the dramatic change in energy prices and availability beginning in 1973 is clearly evident and appears to be mostly a consequence of reduced use of oil and gas.

In Figure 6 the percentages shown are average exponential growth rates calculated by linear least squares fitting of the logarithms of the annual emissions. Although the trends indicated in Figure 6 for the period following 1973 are based on only nine points and hence are susceptible to some adjustment as additional years are added to the data, the change in growth rates around 1973 is quite evident. The pre-1973 4.5 percent annual rate of growth in CO_2 emissions from all fossil fuels has been reduced to less than half that. Carbon dioxide emissions from oil and gas show the 1973 change even more clearly. The apparent small increase shown in the growth rate in coal production following 1973 must be considered in terms of the relatively short period over which the 2.57 percent annual rate was determined. The basic change in total fossil fuel use that occurred in 1973 could be quite important. Rates of growth of CO_2 emissions that were occurring with "cheap energy" are unlikely in the near future.

Although the estimated uncertainty in the CO_2 emissions is about 10 percent, the trend of increasing emissions from fossil fuels is firmly

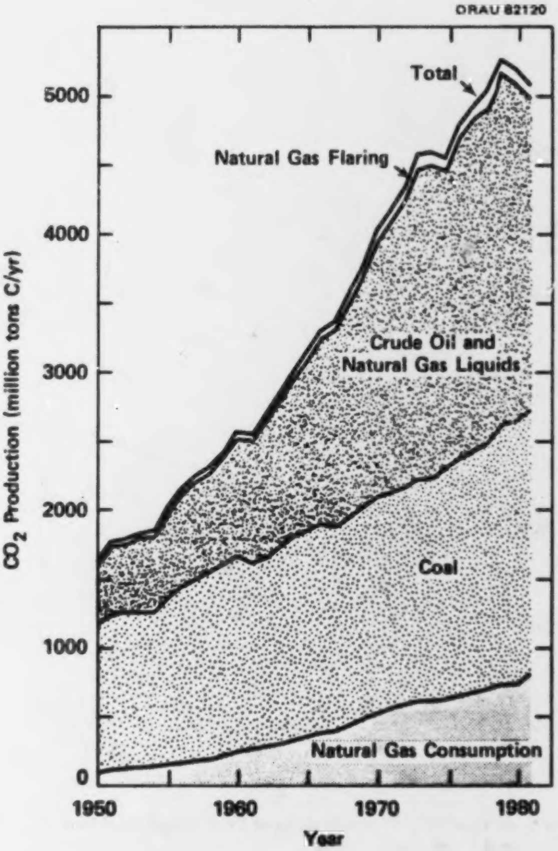

Figure 5. Annual CO_2 production from fossil fuel burning, 1950–1981.

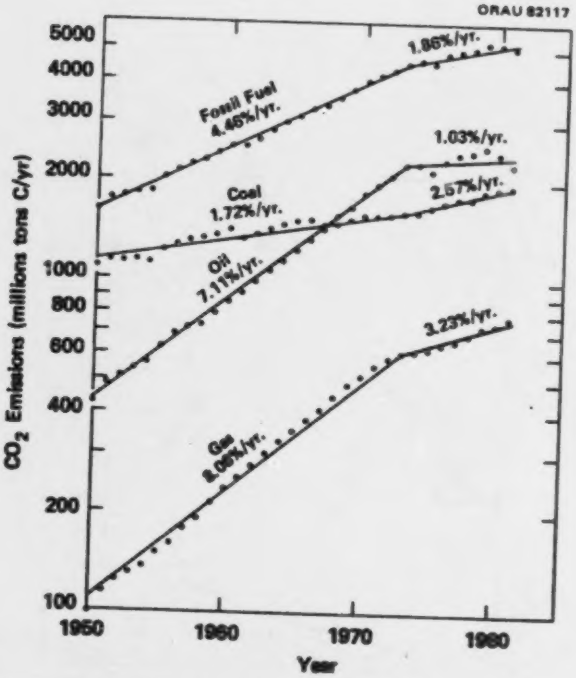

Figure 6. Annual CO_2 Production from Each Fossil Fuel Group and Total Fossil Fuels.

established. There may be a small time-dependent error in the emissions calculation but the 1950-1973 annual growth rate cannot be far from the 4.5 percent per year calculated here and, although not yet well defined, the growth rate following 1973 is about half the earlier rate. Even prior to the 1981-82 recession (during which the emissions actually decreased for two consecutive years) the reduced growth rate was clearly evident.

ACKNOWLEDGMENTS

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We are indebted to William Clive and his staff of the Energy Statistics Branch of the United Nations Department of International Economic and Social Affairs and to J. E. Horwedel of the Carbon Dioxide Information Center, Oak Ridge National Laboratory for their assistance with the world energy data. We also appreciate the suggestions of C. D. Keeling, A. M. Perry, W. P. Elliott and several other reviewers and the help of N. Mynatt and E. Ayres in the preparation of the manuscript.

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DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

FRIDAY, MARCH 4, 1983

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:45 a.m., in room SD-366, Dirksen Office Building, Hon. Pete Domenici, presiding.

Present: Senators Domenici, Ford, and Melcher.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator **Domenici**. Please come to order. Dr. Brewer, we welcome you here. Today's hearing will review the Department's budget request for 1984 for nuclear energy programs and if those programs include commercial nuclear waste, advanced nuclear systems, breeder reactor systems, fuel cycle, naval reactors, and we will not be covering the breeder reactor systems today.

Dr. Brewer, you have some people with you. Perhaps for the record, we should identify them and then your statement will be made a part of the record and you can proceed as you see fit to best summarize it.

STATEMENT OF HON. SHELBY T. BREWER, ASSISTANT SECRETARY, NUCLEAR ENERGY, DEPARTMENT OF ENERGY, ACCOMPANIED BY JOHN GEIDL, DIRECTOR, OFFICE OF COAL, NUCLEAR, ELECTRIC AND ALTERNATE FUELS, ENERGY INFORMATION ADMINISTRATION; WILLIAM R. VOIGT, JR., DEPUTY ASSISTANT SECRETARY FOR URANIUM ENRICHMENT AND ASSESSMENT, OFFICE OF NUCLEAR ENERGY; AND DR. FRANKLIN COFFMAN, DIRECTOR, OFFICE OF TERMINAL WASTE DISPOSAL AND REMEDIAL ACTION PROGRAMS

Dr. **Brewer**. Fine, thank you, Mr. Chairman. I have with me on my far left John Geidl of the Energy Information Agency, a branch of the Department of Energy. On my immediate left is Bill Voigt, head of the enrichment program in the Department. On my right, is Dr. Frank Coffman, who is responsible for the remedial action, TMI, and West Valley programs.

I do have a rather lengthy statement. I will not inflict that on you except to enter it for the record and hold my oral remarks to a few minutes.

The written statement, Mr. Chairman, does contain a section on the breeder and I apologize for that. It was a clerical oversight. I will not touch on that today in my oral remarks.

Senator **Domenici**. That is all right, fine. It never hurts to have more than we ask for.

Dr. **Brewer**. The theme, Mr. Chairman, of the administration's nuclear policy is that we will concentrate on a few major national objectives rather than an endless array of small-level-of-effort programs which do not in sum add to a national mission on nuclear energy.

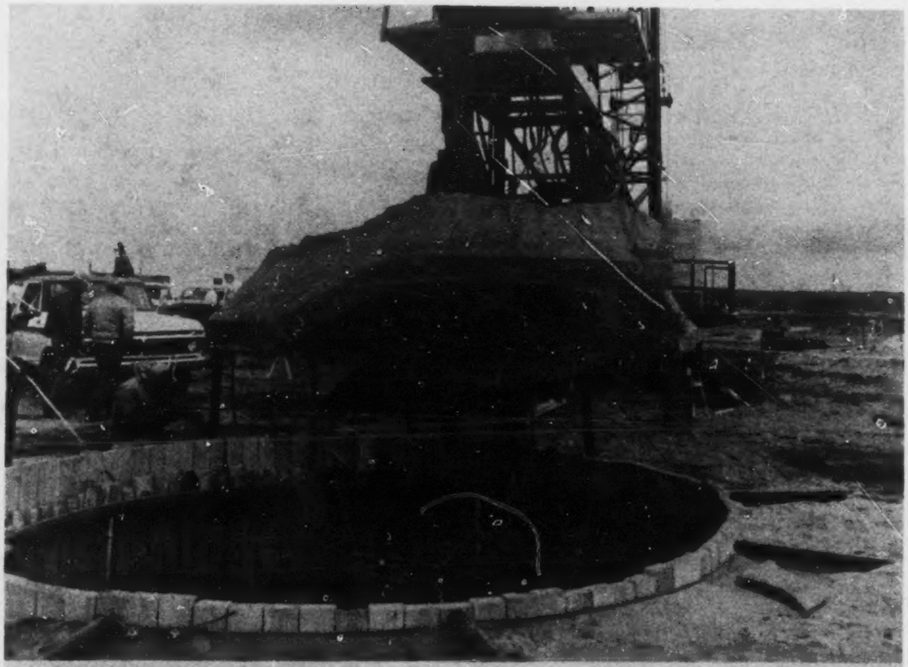
Our desire is to get the job done, not to perpetuate the effort or continue to burden the budget. Our principal objectives are few and important. Some of our major efforts are not major budget items. And those that are, we are attempting to move off budget to funding by non-Federal institutions.

Senator **Domenici**. You do not mean take it off the budget; you mean to get out of the budget.

Dr. **Brewer**. Yes; get them out of the budget. For example, the user fee for the waste bill that was passed last year, and the examination of innovative financial schemes for Clinch River, et cetera.

Senator **Domenici**. All right.

Dr. **Brewer**. We are not asking for more money and making more promises this year, Mr. Chairman. In fact, we are asking for less compared to fiscal year 1982. Before I discuss the fiscal year 1984 budget, I would like to review what we have accomplished in the past year against what we promised that we would do.



ES STARTER HOLE

The waste bill, as you know, passed and the program, which has been characterized over the years as being slow, is now sharply focused. You see here in slide I an exploratory shaft, which we began this past fall in Richland, Wash., at the basalt waste isolation project [BWIP] site. So we are moving on that and we are delighted that the waste bill passed.

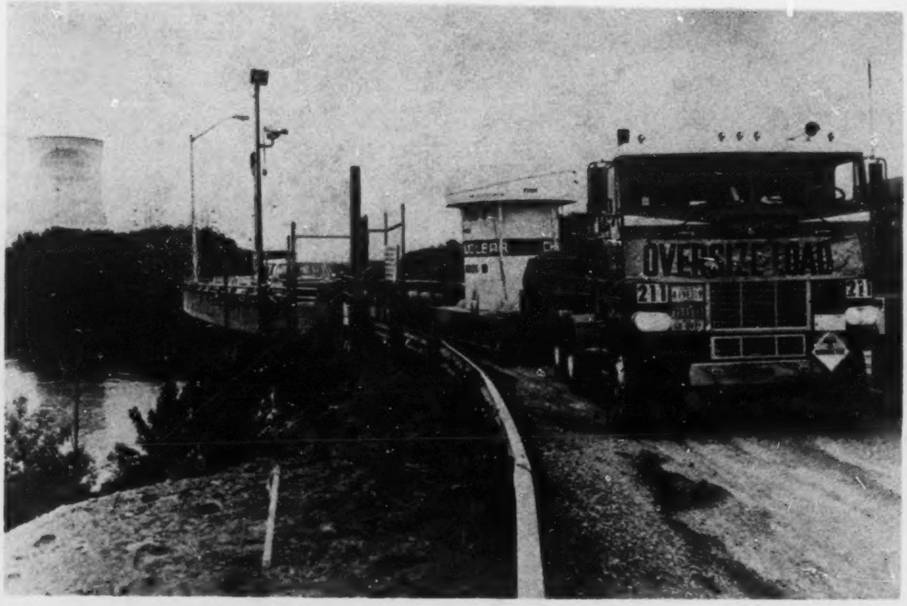
That program is now off budget. We have established a separate project office in the Department reporting directly to the Secretary to implement the provisions of the Nuclear Waste Policy Act. Another major initiative is in licensing reform. We will be submitting recommendations to the Congress in the very near future on licensing reform.

Senator **Domenici**. Licensing reform as applies to what?

Dr. **Brewer**. To the Nuclear Regulatory Commission process for licensing nuclear plants. As you know, the leadtime for plants now is something like 12 to 14 years or more, and we feel that we can shave at least half of that off by streamlining the licensing process.

Senator **Domenici**. So you are suggesting that in that particular area that you think there are ways to administratively streamline it?

Dr. **Brewer**. I think, Mr. Chairman, that there certainly are ways of administratively streamlining the process. We are seeking legislation, however, to protect the process against future changes.



We promised last year to start moving the nuclear waste off of Three Mile Island. Slide 2 is a picture of a truck carrying a canister containing a submerged demineralized system [SDS] liner which has picked up the decontamination from the cell water. About half of the waste backlog is now off the island.

In enrichment, we are making every effort to remain competitive in the world market and in the domestic market for enrichment services. We are pressing ahead with process buildings one and two of GCEP, our gas centrifuge project at Portsmouth. We began this year the test training for the first set of machines at the Oak Ridge test facility.

We have taken steps to prove to both our current customers and potential customers that our product can compete in the long term and in the near term.

Senator **Domenici**. Doctor, would you hold just for a moment, I want to ask a question. Thank you.

Dr. **Brewer**. In addition, Mr. Chairman, we will be offering this spring a new contract for our enrichment services—a contract which will permit greater planning flexibility for our customers and a more stable market forecast for our strategic planning purposes.

I would like now to turn to fiscal year 1984 and begin by telling you that we have a number of different types of programs in the nuclear area in the Department of Energy. We have defense related programs, such as the naval reactor program. We have programs of an operational character, such as uranium enrichment. We have programs such as the space nuclear program, which we perform as a service to other Federal agencies.

Finally, we have programs of a developmental character, which result from or are based on conscious policy choices of the executive branch and Congress. I would like to lay out the architecture of the fiscal year 1984 submission with that in mind.

Assistant Secretary for Nuclear Energy Fiscal Year 1984 Budget Request

Of the $4.0 billion included in the fiscal year 1984 nuclear energy budget, $1.2 billion is included in the energy supply R&D appropriation and the new nuclear waste fund.

	Billions
Total	$4.0
Less defense activities (naval reactors)	−0.6
Less production operations (uranium enrichment)	−2.2
Energy Supply R&D (nuclear fission)	1.2

As shown in slide 3, the total nuclear budget is $4 billion. If you subtract the naval program and the uranium enrichment program, the remainder is $1.2 billion.

Assistant Secretary for Nuclear Energy Fiscal Year 1984 Budget Request

Of the $1.2 billion energy supply R&D appropriation, 693 million is for programs intended for commercialization.

	Millions
Total	$1,151
Less noncommercial programs:	
Waste management and waste fund activities	−330
Remedial actions	−94
Advanced nuclear systems (space)	−34
Fission programs intended for commercialization	693

Incidentally, the $2.2 billion in outlays for the enrichment program is matched by revenues of that amount.

As I said before, we now have the high level waste management program off budget. Looking at slide 4, there is the $330 million paid for by user fees. We also have remedial action programs which have a legislative basis. We also have the nuclear space program at $34 million; this is a program we conduct for others.

After starting at $4 billion, we have now come down to $693 million for fiscal year 1984. And you can see, Mr. Chairman, these are programs, as I said before, which have commercialization potential, and which result from policy choices of the administration and Congress. Included are programs for research and development of breeders, converter reactors and the fuel cycle.

ASSISTANT SECRETARY FOR NUCLEAR ENERGY FISCAL YEAR 1984 BUDGET REQUEST PROGRAMS INTENDED FOR COMMERCIALIZATION

	Fiscal year—		
	1982	1983	1984
Breeder reactors	642	550	603
(CRBR)	(194)	(194)	(270)
Converter reactors	95	79	53
Fuel cycle	53	43	37
Total	790	672	693

Note.—Total program reduction (1982 to 1984) = 12 percent. Reduction of programs other than CRBR = 29 percent overall, 11 percent fiscal year 1983. Total increase from 1983 to 1984 = 3 percent.

And you can see, on slide 5, Mr. Chairman, that compared to fiscal year 1982, we have reduced our request by 12 percent. If you exclude Clinch River, we have reduced the budget request by 29 percent.

Senator **Domenici**. Are these outlay numbers, Doctor, or budget authority?

Dr. **Brewer**. These would be a budget authority number.

Senator **Domenici**. Let me just correct for the record, when you use the term off budget, what you really mean is it pays for itself.

Dr. **Brewer**. Yes, sir. When I use the term off budget, I mean either one of two sources of funding, either a user fee of some sort or another source of revenue, such as, an institution, other than direct appropriations.

Senator **Domenici**. The problem we have is that in the sense of this committee of budget appropriations, their on budget is just that the revenues show up some place else. So we have a constant education process as to whether something is really going up or not when the net effect is to cancel its cost.

In our lingo up here, off budget means that it is not accounted for in the budget or the appropriations process at all. That is not what you mean.

Dr. **Brewer**. No, sir. In fact, in the enrichment case, for example, Mr. Chairman, those funds are appropriated and authorized by this committee and others, but they are matched by revenues which go straight to the Treasury.

Mr. Chairman, this completes my formal remarks and my colleagues and I would be happy to answer whatever questions you may have.

[The prepared statement of Dr. Brewer follows:]

STATEMENT OF SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
U.S. SENATE
MARCH 4, 1983

Mr. Chairman and Members of the Committee, I am pleased to appear before you today to discuss the proposed Department of Energy fission energy budget. The FY 1984 funding request for nuclear programs is $837 million in budget authority. This compares to $760 million for FY 1983. Distribution of the funds among the program elements is as follows:

	FY 1983	FY 1984
	(in millions)	
Uranium Enrichment	$1,942	$2,240
Uranium Enrichment Revenues	-1,968	-2,240
Commercial Waste Management	18[1/]	16[1/]
Remedial Actions	63	94
Breeder Reactor Systems	550	603
Converter Reactor Systems	79	53
Fuel Cycle	37[2/]	37[2/]
Advanced Nuclear Systems	39	34
Total	$ 760	$ 837

[1/] Excludes $24 million in FY 1983 and $7 million in FY 1984 for activities now managed by the Nuclear Waste Policy Act Project Office.

[2/] Excludes $6 million in FY 1983 and $5 million in FY 1984 for activities now managed by the Nuclear Waste Policy Act Project Office.

Mr. Chairman, the agenda that I am proposing for FY 1984 should hold few surprises for the Committee. Last year, when I appeared before you, I announced a realignment of my programs and organization to conform with and be responsive to the nuclear policy that President Reagan had announced in October of 1981. I also told you that I had introduced a "management-by-objective" approach into nuclear programs that allowed for concentration on major goals and elimination of work not directly related to the President's policy initiatives. As a result, we have made real progress toward meeting the President's policy objectives: specifically, waste legislation is in hand, Clinch River is progressing on an accelerated schedule, and we are ready to submit licensing reform legislation. In addition, notable progress continues at TMI, GCEP, and West Valley. Very recently a Memorandum of Understanding was signed by DOE, NASA, and Defense which provides a framework for our space reactor effort. These achievements demonstrate our resolve to produce results rather than engage in protracted study.

I would like to point out that the programs we have planned for FY 1984 are entirely consistent with the appropriate Government role in energy development as defined by the Administration. The elements of this role as applied to nuclear energy include:

- stabilizing Federal policy for time periods commensurate with the leadtimes required in nuclear development;
- removing unnecessary regulatory impediments that have developed over the years;
- fulfilling Federal responsibilities for certain elements of the fuel cycle, such as uranium enrichment; and
- conducting high-cost, high-risk, research and development that is of significant benefit to the Nation but beyond the current capability and resources of the private sector.

Before describing the program elements in detail, I would like to comment briefly on some of the highlights and issues in our nuclear program.

URANIUM ENRICHMENT

The actual cost to the taxpayer of the FY 1984 uranium enrichment program is zero. We expect to realize $2.24 billion in enrichment revenues which will completely offset the requested funds. Uranium enrichment has been an enterprise of the United States Government, dating back to the days when it was developed for defense purposes. Since that time, we have provided enrichment services to both domestic and foreign civilian customers.

Prior to 1974, the United States was the only enrichment supplier in the world market. Today the USSR and two consortia (URENCO and EURODIF) are our active competitors. By utilizing extremely aggressive marketing strategies, this competition has been able, in one decade, to reduce the U.S. share of the foreign enrichment market from 100 percent to about 30 percent. In addition, significant inroads are being made in our domestic enrichment sales. Our market performance in the future will depend primarily on our ability to offer low-cost enrichment services under favorable contract terms.

To meet this challenge, we are taking a number of actions which are designed to enhance the market position of the U.S. uranium enrichment program.

Specifically, steps are being taken to minimize the current selling price by reducing costs and optimizing enrichment production activities. Our success in this area is reflected in our recent announcement that there will be no increase this year in the charge for enrichment services. A new enrichment contract, the Facility Requirements (FR) contract, is also under development to provide needed stability between enrichment commitments and actual requirements by offering greater contract flexibility to customers. Finally, advanced, low cost technologies are being developed and deployed on a schedule designed to make the most economically attractive enrichment services available to U.S. customers in the post 1990 time period.

Currently we are enriching uranium by means of the gaseous diffusion process. A far more cost effective process is gas centrifuge. In addition to providing separative work units (SWUs) at a significantly lower cost than is currently possible, the centrifuge process uses approximately 5 percent of the energy that gaseous diffusion consumes. We are constructing the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. Construction progress has been excellent and we expect the first increment of plant production to begin in 1989. A large fraction of the funds we are requesting for FY 1984 will go for GCEP construction. When considering the uranium enrichment request, one critical factor must be kept in mind. Without lower cost enrichment technology, the United States Government will price itself out of the multibillion dollar enrichment business.

Beyond centrifuge, we are developing the Atomic Vapor Laser Isotope Separation (AVLIS) technology which has the potential for additional cost savings and energy consumption advantages. Last spring this process was selected from three candidates for engineering development. While progress to date has been most encouraging, the AVLIS technology is not sufficiently mature to permit deployment before the mid-1990s.

Finally, I would like to point out that in FY 1984 we have decided to operate our gaseous diffusion plants at slightly higher power levels than in FY 1983. This will require the purchase of an additional 530 megawatts of power, which, incidentally, will reduce demand charges for power not purchased. The increase in power is in response to recent technical studies which concluded that prolonged plant operations below design levels could incur risk of equipment failure. Continued operation at lower power levels also jeopardizes the Department's ability to meet scheduled customer deliveries in a timely manner.

WASTE MANAGEMENT

The progress made over the last year in the area of waste management is an accomplishment of which we can all be proud. With the passage of the Nuclear Waste Policy Act we have a basis in law for a sharply focused program and a definite schedule.

A key feature of the Act, as you know, was the establishment of a system of fees, paid by the utilities, to fund the waste programs that are directly related to commercial nuclear waste disposal. We have long felt that the beneficiaries of nuclear power should bear the cost of disposing of the waste. This transition from Government to commercial funding will impact the FY 1984 budget as offsetting revenues realized from fee collection are deposited in the Nuclear Waste Fund account. Programs not covered under the Waste Fund, such as Remedial Actions and the West Valley Demonstration Project, will remain a Federal funding responsibility.

Secretary Hodel has appointed Mr. Robert Morgan as the Director of the interim Nuclear Waste Policy Act Project Office and has detailed a sizable contingent of personnel to ensure that the near term legislated requirements are met. Preparations for establishing the office on a permanent basis are under way. I am confident that the Department will swiftly and effectively implement the Act. Mr. Morgan will be testifying regarding the details of the programs to be conducted under the Nuclear Waste Policy Act.

Included in the programs not covered under the Waste Act is the Department's responsibility for remedial actions at sites contaminated as a result of prior U.S. Government activities. Work is divided among four major programs. The Formerly Utilized Site Remedial Action Program (FUSRAP) has identified 35 sites throughout the country as requiring stabilization or removal of contaminated material. We are now performing the required work at the 14 sites for which DOE has remedial action authority. Our uranium mill tailings remedial action (UMTRA) program is directed toward the cleanup of 24 former processing sites and an estimated 5,000 to 6,000 vicinity properties contaminated by mill tailings from uranium mining and processing. A third program covers our participation in a Federal/State cooperative effort to remove uranium mill tailings used for construction purposes in Grand Junction, Colorado. At the close of FY 1984, we will have completed remedial actions at 612 of the 626 structures requiring attention. A fourth program manages and arranges for disposition of facilities formerly used for civilian nuclear energy development. About 80 sites are currently identified for work, including the Niagara Falls Storage Site, selected buildings at the Mound Facility in Ohio, and the Shippingport Atomic Power Station. This program is developing improved technology and methods for facility decontamination and decommissioning (D&D) that will be of substantial benefit to industry in retiring nuclear plants from operation.

Finally, we are conducting a demonstration of high-level waste solidification at the Western New York Nuclear Center, near West Valley. After solidification technology has been developed, we will oversee the D&D of the West Valley facilities used in connection with this Project and will direct disposal of the resulting wastes. Our solidification work at West Valley is coordinated with our generic Waste Treatment Program, which is developing the waste package technology for repository disposal.

BREEDER REACTOR SYSTEMS

Our breeder reactor request for FY 1984 shows a slight increase over the FY 1983 appropriation. A substantial fraction of that request is for the Clinch River Project. I am well aware that support for this Project is far from unanimous but without rehashing the arguments for and against its continued funding, I would like to review briefly the historical breeder strategy that incorporates CRBR as a necessary element.

In 1967, when we concentrated our efforts on a single breeder technology--the Liquid Metal Fast Breeder Reactor--several alternative developmental strategies were considered. The strategy that emerged as having consistently the best potential for both safety and economics was to build a series of plants of increasing size that could demonstrate the critical elements of component and plant development. This scaleup approach was used to develop the light water reactor for commercialization. It has also been the strategy of choice for all other nations actively developing a breeder option.

Two reactors in the scaleup series--EBR-II and FFTF--have been built and are operating. The Clinch River Plant, which is the last step before building a commercial-size plant, is moving toward the construction stage. The plant design, which is at the forefront of technological advance, is approximately 90 percent complete. More than 70 percent of the major equipment and components have been delivered or are on order.

The licensing process, resumed in September 1981, is proceeding exceptionally well. Last August NRC granted our request to begin site preparation and in September work was initiated. We have completed the site suitability and environmental requirements for licensing and we expect NRC to issue its Safety Evaluation Report in March. NRC authorization to begin safety-related construction activities is expected by November of this year. Overall, CRBR licensing is moving at a faster pace than that of any light water reactor over the past five years. We believe this performance attests to the technological sufficiency of the plant design.

Despite these technical achievements, the Clinch River Project and, as a result, the entire breeder program are facing a critical juncture. The technology is close to commercial viability, but the financial resources necessary to complete CRBR are in question.

Clinch River was conceived as a joint venture between Government and industry with each bearing an equitable share of Project costs. The original industry financial commitment to CRBR funding was based on a cost estimate derived in 1972. Since that time, a combination of factors, including inflation and costly delays from Federal policy changes, have sharply escalated Project costs. The once equitable industry commitment is no longer sufficient to balance the large outlays that the Government must make to complete the Project. As you know, CRBR funding was provided for FY 1983 with a requirement for a vigorous exploration of possible methods of reducing Federal budget outlays. In response, the utility industry has established a task force of senior financial executives to prepare proposals for greater industry cost-sharing in the Project. Recommendations are to be forwarded to the Congress by March 15, 1983. It is my hope that the commitment of the private sector to the Clinch River Project is such that viable financing arrangements will be forthcoming.

CONVERTER REACTORS

The Converter Reactor Program is directed toward improvements in the Light Water Reactor technology and resolution of regulatory, financial, and institutional problems adversely affecting the nuclear industry. In the first instance, we are serving as the coordinator of a DOE/NRC/industry cooperative program to develop a systematic and integral approach to LWR safety. This responsibility was established by the Nuclear Safety Research, Development, and Demonstration Act of 1980. We are also participating in an international cooperative program to improve reactor response to accident conditions, making use of the unique capabilities of the Loss of Fluid Test (LOFT) facility. As an extension of our technical safety activities, we are cooperating with NRC, the Electric Power Research Institute and General Public Utilities in the cleanup of the damaged TMI-2 reactor. DOE's role is to accept unique radioactive waste, including the damaged core, for research and development of generic value to increased reactor safety and reliability.

Our role of assisting in the resolution of problems currently hindering the LWR industry is in response to the President's directive. We have prepared recommendations for licensing and regulatory reform that we believe will better serve the interests of, first and foremost, the general public; secondly, the regulators; and third, the industry which designs, constructs and operates nuclear power plants. We intend to submit legislation early in this session of Congress.

FUEL CYCLE PROGRAM

The technical objective of our Fuel Cycle Program is to develop advanced technology for reprocessing of fuels. Efforts are focused on the more stringent requirements associated with reprocessing of fast breeder reactor fuel which has higher thermal and radiation burdens, higher fissile content, and sodium contamination. This technology will also be available for future LWR fuel reprocessors.

We continue to feel strongly that reprocessed fuel has significant advantages over disposal of spent fuel on the basis of fuel conservation, nonproliferation, environmental, and economic considerations. As you know, the Continuing Resolution for FY 1983 instructed the Department to complete our safeguards evaluation at the Barnwell Plant and to phase out activities by July 31, 1983. Accordingly, we have requested no funds for Barnwell in FY 1984. We remain hopeful, however, that some private sector initiative will be forthcoming whereby this valuable commercial facility will be allowed to operate.

ADVANCED NUCLEAR SYSTEMS

The final program I would like to mention is our development of Advanced Nuclear Systems in support of U.S. military and civilian space missions. Since 1961, the United States has launched 22 NASA and military space systems having all or part of their power requirements supplied by nuclear power sources. These include the missions by Pioneer, Viking, and Voyager. We are currently developing nuclear isotope power generators for the NASA Galileo spacecraft and the NASA/European Space Agency spacecraft, both planned for launch in 1986. Another major activity is the development of space nuclear power reactors in cooperation with NASA and DOD.

SUMMARY

Mr. Chairman, in closing I would like to place the nuclear request for FY 1984 in perspective. It is important to remember that many of the programs are legislatively mandated and outside the scope of energy research and development. Examples are the Naval Reactor and Uranium Enrichment programs. When these are subtracted from the total request, there remains $837 million for energy supply R&D. Of that $837 million, $144 million is for noncommercial programs including waste management, remedial action responsibilities, and advanced nuclear systems activities in support of NASA and DOD missions. This leaves $693 million for fission energy R&D programs, i.e., breeder reactors, converter reactors, and the fuel cycle. These programs, which are ultimately intended for commercialization, are somewhat discretionary in character--that is, technologies that we are pursuing as a result of a conscious policy decision. The breakdown of funds is portrayed below:

	FY 1984 (in millions of $)
Total ASNE Budget	$1,450
Less:	
o Defense Activities (Naval Reactors)	-613
o Production Operations (Uranium Enrichment)	-2,240
o Revenue from Enrichment	+2,240
o Total Energy Supply R&D (Fission)	837
Less:	
o Waste Management	-16
o Remedial Actions	-94
o Advanced Nuclear Systems (Space)	-34
Programs Intended for Commercialization	693
o Breeder Reactors (CRBR)	-603 (270)
o Converter Reactors	-53
o Fuel Cycle	-37

I would like to point out that the $693 million requested for programs intended for commercialization represents only a 4 percent increase over the FY 1983 figure.

I recognize the difficult choices that Congress faces in its authorization and appropriation decisions. All programs have their attractive and supportable features and in more affluent times we could perhaps be less stringent in our funding selections. In view of the austere Federal budget, we have reexamined the nuclear program and have limited our efforts to activities that are sharply focused on a few critical objectives. We believe, Mr. Chairman, that the request we are presenting for FY 1984 is as lean as we can make it and still do the job.

With the exception of Breeder Reactor Systems, I will now describe the elements of the fission program in detail.

URANIUM ENRICHMENT

The goal of the Uranium Enrichment Program is to meet domestic and foreign utility and United States Government requirements for uranium enrichment services in the most economical, reliable, safe and environmentally acceptable manner possible.

The FY 1984 budget request for the Uranium Enrichment Program is $2,240,000,000 for authorization and appropriation, offset by $2,240,000,000 in projected revenues.

Projection of Uranium Enrichment Requirements

The Office of Uranium Enrichment and Assessment periodically estimates the domestic and non-U.S. nuclear electric generating capacity that will be served by the United States uranium enrichment complex.

Our mid-range estimate made last summer projected online worldwide nuclear power capacity to be served by United States uranium enrichment capacity to be 135 gigawatts in 1985, 178 gigawatts in 1990 and 204 gigawatts in 1995. Domestic nuclear power capacity included in these totals are 87 gigawatts in 1985, 119 gigawatts in 1990, and 123 gigawatts in 1995. The domestic forecast is based only on reactors currently operating or under construction. Our total forecast estimate is lower than projected in last year's testimony by 2 gigawatts in 1985, 4 gigawatts in 1990 and 22 gigawatts in 1995. The reduced estimate reflects additional delays and/or cancellations of nuclear power projects.

Long-Term Strategy

A long-term production strategy is necessary to permit orderly planning to meet projected uranium enrichment requirements. The strategy is chosen after considering economics, operational risks, and the flexibilities that are available to respond to higher or lower demand levels. In the short term, the strategy calls for lower operating levels of the gaseous diffusion complex and reduced inventories of enriched uranium. Even though the lower operating levels result in the purchase of power below existing contract levels, requiring the Department to pay capacity charges to its power suppliers for power not purchased, it remains the most economical way to operate. Recently completed technical studies indicate that significant risk is incurred from prolonged plant operation below design levels. Accordingly, in FY 1984, the complex will operate at 3,190 megawatts or 530 megawatts above the FY 1983 level.

The strategy also calls for continued design and construction of the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. The GCEP will initially provide an additional 2.2 million separative work units (SWU) of capacity by 1989 with completion of two process buildings. Completion of the full GCEP (eight process buildings) will be based on either demand for additional capacity or the need to reduce production costs. As less costly gas centrifuge capacity becomes available, the more costly gaseous diffusion plants will be reduced, beginning in the early 1990's. Continued research on advanced gas centrifuge and the atomic vapor laser isotope separation technology provides additional cost reduction opportunities.

United States Competitive Position

At present, the demand for uranium enrichment is relatively static, future sales prospects are limited and uncertain, and many enrichment customers have purchase commitments far in excess of their needs. Some utilities are offering to sell their excess enriched uranium in competition with the primary enrichment suppliers rather than incur substantial inventory costs. This has created a substantial secondary market and corresponding near-term sales perturbations. As a result, a highly competitive situation exists between the primary enrichment suppliers for a fixed market volume. Today, we are facing competitive pressures in the United States and in the international market from several existing suppliers with the following production capacities:

Foreign Enrichment Suppliers and Capacity Levels

Supplier	Capacity (millions of SWU/Year)
Eurodif	10.8 capacity; current production is lower
Urenco	1.0 currently; 2.0 by 1990
USSR	3 currently available for export

In addition to these suppliers, Brazil and South Africa are constructing enrichment plants of modest size, primarily to meet indigenous needs. Japan has announced plans to build a 1 to 2 million SWU plant by 1990 using centrifuge technology in order to realize the announced goal of meeting up to 33 percent of their own enrichment needs. This could limit U.S. sales potential in Japan after 1990. Also, Australia has initiated a feasibility study based on Urenco technology for an enrichment plant which would be available in the mid 1990's. The realization of these enrichment plans will continue to intensify competitive pressures upon the United States.

Delays in nuclear programs, inflationary costs, and an economic slowdown worldwide have all contributed to excess enrichment commitments, large available utility-owned inventories, and associated financial burdens for the nuclear community. This situation, in combination with the pressures of a growing secondary market and aggressive actions by our enrichment competitors, has adversely affected the U.S. share of the enrichment market. In contrast to its previous position of being the sole supplier of enrichment services in 1974, the U.S. share of the non-U.S. market has declined to about 30 percent today. A number of our foreign customers have switched from the U.S. to Eurodif, Urenco and the USSR, and some new business has gone to these suppliers. During 1982, for the first time, a domestic utility terminated its contract with the U.S. in favor of a foreign supplier. To date, the total value of sales the U.S. has lost to foreign suppliers is over $2.0 billion, with about $0.5 billion in lost sales occurring during the last year. In addition to these losses, a great number of direct U.S. sales are being replaced by secondary market transactions. Though sales replacement by excess enrichment commitments originally produced by DOE is understandable, secondary market transactions of non-U.S. enriched material for use as a replacement for U.S. sales is occurring more frequently. Three U.S. utilities and three foreign companies replaced approximately $30 million of potential U.S. sales during 1982 with heavily discounted excess foreign origin enrichment material. All of these sale losses are of great concern to us, and we must reverse this trend.

Price has become the most important sales consideration to enrichment customers. The price advantage of $30 to $50 per SWU enjoyed by the United States in 1981 no longer exists. More and more frequently, both the secondary market and our competitors have offered price guarantees at levels below the U.S. price. Their pricing strategy and the fluctuating exchange rates have further aggravated the U.S. sales position. These competitive forces and large secondary market quantities have created market instabilities and significant sales uncertainties for the U.S. enrichment business. The United States is faced with the need to compete in a highly unstable, low price enrichment market while at the same time financing the capital investments needed to implement advanced, low cost technologies that are vital if the United States is to maintain a market leadership position in the future.

We are taking a number of actions to enhance the market position of the U.S. uranium enrichment program. We are minimizing the current selling price by reducing costs and optimizing enrichment production activities. We are developing a new enrichment contract, the Facility Requirements (FR) contract, to provide needed stability between enrichment commitments and actual requirements by offering greater contract flexibility to customers. Finally, we are developing advanced, low cost technologies and deploying them on a schedule designed to make the most economically attractive enrichment services available to U.S. customers in the post 1990 time period. If successful, these steps will maintain and eventually expand the U.S. sales base, thereby enabling significant benefits in terms of domestic employment, balance of payments and a meaningful contribution to nuclear policies abroad.

Uranium Enrichment Activities

The budget for Uranium Enrichment Activities as shown in Chart 1 provides funding for three major program activities: (1) Gaseous Diffusion; (2) Gas Centrifuge, and; (3) Advanced Isotope Separation.

CHART 1

URANIUM ENRICHMENT PROGRAM

	Budget Authority (Dollars in Thousands)	
	FY 1983	FY 1984
Uranium Enrichment Activities		
Gaseous Diffusion		
Cascade Power	884,000	$ 1,184,000
Other Operations and Support	316,353	297,300
Total Gaseous Diffusion	1,200,353	1,481,300
Gas Centrifuge		
GCEP	588,000	572,000
Other Operations and Support	94,500	109,800
Total Gas Centrifuge	682,500	681,800
Advanced Isotope Separation	50,633	73,000
Program Direction	3,650	3,900
Total Uranium Enrichment Activities	$ 1,937,136	$ 2,240,000
Uranium Resource Assessment	5,000	0
Subtotal	1,942,136	2,240,000
Uranium Enrichment Revenues	-1,968,319	-2,240,000
Total, Uranium Enrichment Program	$ -26,183*	$ 0

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* The net FY 1983 appropriation, after revenues, is $0. The number shown reflects comparability adjustments.

Gaseous Diffusion

The United States presently enriches uranium to the desired U-235 product assay in the gaseous diffusion plants located at Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky. In these plants, the United States enriches customer-provided natural uranium in the U-235 component for a fee which recovers the cost of providing the services.

In FY 1984, $1,481,300,000 is requested for operation of the gaseous diffusion complex. The three gaseous diffusion plants will operate at a power level of 3,190 megawatts in FY 1984 and produce about 12.1 million SWU. The FY 1984 operating level is consistent with our long-term enrichment strategy and represents an increase of 530 megawatts above the FY 1983 level of 2,660 megawatts. Recent technical studies indicate that prolonged operation below 3,190 megawatts would run a significant risk of extensive equipment failures. This could result in the loss of plant capacity and the release of radioactive material.

The 3,190 megawatt power level is substantially below the 5,781 megawatts we are contractually committed to purchase under existing contracts with the three power suppliers. Consequently, we are contractually required to pay about $243,000,000 in capacity charges in FY 1984 (Tennessee Valley Authority (TVA)--$226,000,000, and Ohio Valley Electric Corporation (OVEC)--$17,000,000) for power under contract that will not be purchased. If the Department purchased power at the contractually committed level of 5,781 megawatts, the FY 1984 power budget would be increased by $680,000,000 from $1,184,000,000 to $1,864,000,000.

We are continuing discussions with the power suppliers in an attempt to reduce the capacity charge payments for power not purchased. As in the past, the success of these negotiations depends on the ability of our power suppliers to transfer contract power not purchased by the Department to other customers. Relief from OVEC for FY 1984 is heavily contingent upon the level of economic activity in the Midwest. Relief from TVA is unlikely at this time because of the surplus generating capacity within TVA's own system, as well as within neighboring systems.

The total FY 1984 cascade power budget, including $226,000,000 in TVA capacity charges, is $1,184,000,000. This is an increase of $300,000,000 over the FY 1983 budget and is due to the purchase of the additional 530 megawatts, increases in the cost of power purchased and increased capacity charges for power not purchased.

Funding requested for diffusion operations, process and long-range technical support, supporting services, capital equipment and construction is $297,300,000. This is a net decrease of about $19,100,000 from the comparable FY 1983 budget. The major decreases are in the requirements for capital equipment and line item construction projects. The only budget increase is in the plant operations account primarily related to existing labor agreements. The requested funds are the minimum amounts needed to operate the plants; to replace equipment that has exceeded its useful life; to properly maintain the plants; and to comply with environmental and safety standards.

New construction projects for the gaseous diffusion program include: storage yards and cylinders for UF_6; general plant projects; utilities upgrading; intermediate gas removal; and power systems protection improvements.

Funding is also requested to continue projects authorized in previous fiscal years.

Gas Centrifuge

The FY 1984 budget request contains $572,000,000 for the construction of GCEP and $109,800,000 for other centrifuge activities.

The GCEP will provide an additional 2.2 million SWU per year of capacity by 1989. This GCEP capacity will be increased to 3.3 million SWU per year through upgrading with advanced gas centrifuge machines now being developed; even further advancement in centrifuge machines now appears achievable.

DOE continues to support the need for GCEP based on the results of the Department's thorough analyses of the alternatives available to the enrichment enterprise. These analyses carefully examine various production scenarios and evaluate the merits of each on the basis of cost, both to the Government and to the customer; impact on U.S. enrichment prices and our competitive position in the international market; energy efficiency; and technical achievability. Construction of GCEP will yield superior benefits both to the Government and its customers in terms of improved economics and production reliability. Even at reduced demand levels, the cost of production from GCEP in current year dollars will be significantly lower than production from the existing electricity intensive gaseous diffusion plants (GDPs). When escalation is factored in, the difference between GCEP and GDPs becomes very large.

The rapid deployment of enrichment technologies capable of reducing U.S. production costs is a necessary and prudent business decision. Our centrifuge technology is the most advanced proven enrichment technology in the world and offers the U.S. the opportunity to halt the erosion in our existing enrichment contract base and to regain its leadership and market share in the international nuclear community. The Advanced Gas Centrifuge and the Atomic Vapor Laser Isotope Separation technologies currently under development by the Department offer the promise of even lower future costs but must reach a more mature stage of development before they can be counted on for production planning.

We have emphasized to all existing and potential customers that appreciable cost reductions are expected in the U.S. enrichment program by virtue of U.S. leadership in and utilization of advanced enrichment technologies. Our customers universally accept the concept that future enrichment prices will be more favorable with the incorporation of the more economical, less energy intensive centrifuge technology being installed in GCEP.

Without GCEP, U.S. enrichment prices will be perceived by our customers as being significantly higher in the future. This fact has been emphasized by our competitors, Eurodif and Urenco. Our competitors stand to gain a considerable market advantage if the potential of GCEP is not realized in the U.S. Though a detailed estimate of potential sales losses is not possible, the continued strength and vitality of a U.S. Government enterprise which produces $2 to $3 billion in annual revenues, of which about one-third represents a positive contribution to the U.S. balance of payments position, is a worthwhile consideration. In this regard, the commitment to building GCEP is a major positive force.

GCEP is making excellent progress and is on schedule with the total estimated cost (adjusted for escalation) constant. Project momentum continues at a high rate as construction progresses. Process Buildings No. 1 and No. 2 are enclosed. In Process Building No. 1, the floor modules for the centrifuge machines and electrical, heating and ventilation systems are installed. Process piping is under contract and installation is proceeding. Site preparation and rough grading for all eight process buildings is complete. The Recycle/Assembly Building is enclosed and a portion of the building has been turned over to the operating contractor. The fire station, central receiving warehouse, mobile equipment garage, the administration building, electrical substations, and several support buildings are finished. Work on the central control room, the Feed and Withdrawal Building and utilities is underway. Through FY 1983, $2,173,520,000 has been authorized and $2,127,845,000 appropriated, with costs of $1,811,493,000 against a total estimated project cost of $7,450,000,000 in FY 1984 dollars. Design of the GCEP Project is over 89 percent complete with seven of the nine major architect engineers having finished their design efforts. Three centrifuge machine manufacturers have constructed and are operating manufacturing facilities in Ohio and Tennessee using corporate funds. All of the centrifuge manufacturers are now fabricating centrifuge machines on production tooling. Centrifuge machines are operating in the Life Test Facility and the Centrifuge Plant Demonstration Facility (CPDF). The CPDF is a full cascade which will be replicated many times in GCEP. Other manufacturing facilities for materials and components for the GCEP project are in place and in production.

In August of 1982, the CPDF became operational with industrially supplied centrifuges. Start-up, operation, and performance of the machines to date have exceeded all expectations in terms of machine reliability and capacity. The balance of plant equipment operation has been equally successful.

The FY 1984 request for other centrifuge operations and support includes funds for startup testing, procedures, and training to support operation of the GCEP. Also included are funds for the Advanced Gas Centrifuge development program, capital equipment and construction. The FY 1984 budget request for these activities is $109,800,000, an increase of $15,300,000 over FY 1983. Costs for GCEP startup activities are increasing by $21,700,000 over FY 1983 and developmental activities are decreasing by $6,400,000. The increase in startup activities reflects the testing of subsystems, preparation of operating and maintenance procedures, and personnel training. These activities are required in order to begin in-plant operational testing in mid-FY 1984, and to assure that Process Building No. 1 becomes partially operational by FY 1985.

The Advanced Gas Centrifuge (AGC) program consists of projects intended to provide production centrifuges with separative capacity substantially greater than the baseline (Set III) centrifuge. The Department is making good progress in demonstrating an advanced centrifuge, designated Set IV, which has separative capacity 1.5 times that of Set III. Efforts, to date, have verified that the speed and improved flow management techniques extrapolated from current technology have the potential of providing the anticipated performance gain. Full-scale centrifuge tests in this program during FY 1983 will establish which design features will optimize overall separative performance and achieve the desire 50 percent improvement.

In early FY 1983, we initiated research and development on a gas centrifuge concept with a potential separative capacity 2 to 3 times greater than the baseline centrifuge. Gas centrifuges developed within this effort are designated as Set V. A key feature of this program is the relatively high payoff it offers for a modest investment. We anticipate that the first phase, which covers two years, will encompass preliminary testing of full-scale machine rotors intended to verify that reliability testing and production design are warranted.

Advanced Isotope Separation

The objective of the Advanced Isotope Separation (AIS) program is to develop and implement a process that has the capability of producing enriched uranium at costs of less than $40 per SWU. In April 1982, the Atomic Vapor Laser Isotope Separation (AVLIS) process was chosen from three competing AIS technologies to proceed to the engineering development phase. The selection of AVLIS resulted from comprehensive technical evaluations of each technology. These evaluations included a risk assessment and an identification of the major technical uncertainties to be resolved prior to the initiation of the detailed design of large scale facilities. For AVLIS technology, the principal uncertainty involved the operability of the uranium collector subsystem. The FY 1983 AVLIS development effort will extensively examine this issue by operating existing testbeds. The goal of this effort is to develop the data base needed to design plant scale testbeds. Efforts will proceed to complete partially constructed testbeds, such as the Materials Handling Development Module (MHDM) which, when operated, will provide a validation of the FY 1983 data base at near plant scale geometries. Experiments will be conducted on enrichment demonstrations using the updated baseline feed and liquid collection of product and tails. Also we intend to complete a new point design using an updated feed concept.

The major AVLIS effort in FY 1984 will be to complete the detailed data package needed to proceed with engineering design and to initiate construction of experimental facilities capable of demonstrating the process at full scale. Technology development funds are also required to provide the information needed to initiate fabrication of the next generation of laser and separator subsystems. In addition, MHDM will become operational at the end of FY 1984. This facility will be used to demonstrate the thermal management of collector subsystems in MHDM. The FY 1984 funding requested for the AVLIS program is required to initiate evaluation of subsystem reliability, lifetime and engineering issues.

Uranium Resource Assessment

Although the data collection portion of the National Uranium Resource Evaluation (NURE) program was terminated in FY 1981, during FY 1982 a tremendous amount of the data were analyzed and made available to the public in reports, maps, and computer tapes. During FY 1983, essentially all of the remaining data gathered through the NURE program will be made available to the public. Thus, the major goals of this program have been achieved.

COMMERCIAL WASTE MANAGEMENT PROGRAM

The elements of the Commercial Waste Management Program include Remedial Action, the West Valley Demonstration Project, Commercial Low-Level Waste, and Waste Treatment. I will also discuss the Three Mile Island Program which is funded under the Converter Reactor Program but managed under the Commercial Waste Management Program.

Remedial Action Program

The objective of the Remedial Action program is to treat or stabilize radioactive wastes and perform required decontamination and decommissioning at contaminated DOE and legislatively dictated non-government facilities and sites. The major program areas are: (1) Formerly Utilized Sites Remedial Action Program (FUSRAP); (2) remedial action at Grand Junction, Colorado (P.L. 92-314, as amended); (3) Uranium Mill Tailings Remedial Action Program (UMTRAP) for inactive uranium mill tailings sites (P.L. 95-604); and (4) management of certain radioactively contaminated Department facilities declared surplus and resulting principally from civilian nuclear energy programs.

The FY 1984 budget request for the Program is $93.98 million as compared to a FY 1983 appropriation of $63.39 million. This also includes funds for the West Valley demonstration of the solidification of high-level radioactive wastes for final disposal (P.L. 96-368).

Formerly Utilized Sites

The Formerly Utilized Site Remedial Action Program (FUSRAP) provides for remedial actions at former nuclear processing facilities, most privately owned, which became radioactively contaminated from Manhattan Engineer District or Atomic Energy Commission activities and which have not been decontaminated sufficiently to meet current health effects guidelines for unrestricted use. Potential health risks limit the utilization of these properties, and property values may in some cases be reduced. To remedy the situation, the contamination will be either stabilized in-place, with restrictions placed on site use, or the contamination will be removed and disposed of at another location. Thirty-five sites have been identified as potentially requiring remedial action. DOE has remedial action authority at 14 sites. Only minimal activity, limited to some preliminary engineering and environmental studies required for planning, will be carried out for non-authorized sites. At sites where remedial action is undertaken, stabilization in place will be the preferred option. Where removal of the contamination is necessary, DOE sites will be utilized for the disposal of small quantities of contaminated material. In other cases, the affected State would be expected to select a new disposal site to be owned by either the Federal or State government. The Oak Ridge Operations Office has the lead field office role in implementing this program.

In FY 1983, the remedial actions begun in FY 1982 at Bayo Canyon and on the upper part of Acid Pueblo Canyon, Los Alamos, New Mexico, have been completed. Remedial action to clean up the main drainage ditches from the Niagara Falls Storage Site (NFSS) in New York will be completed.

Design engineering will be initiated for remedial action at the Shpack, Massachusetts landfill; at Middlesex, New Jersey municipal landfill; and at Linde Air Products in Tonawanda, New York. Preliminary engineering will be completed for the remedial action at the DuPont Deepwater, New Jersey plant.

In FY 1984, design engineering and NEPA documentation will be completed at Linde Air Products in Tonawanda, New York; DuPont in Deepwater, New Jersey; and Middlesex Landfill and Middlesex Sampling Plant Phase III in Middlesex, New Jersey.

Grand Junction

Under Title II of Public Law 92-314, Congress authorized financial assistance to the State of Colorado, to limit radiation exposure resulting from the use of uranium mill tailings for construction purposes in Grand Junction, Colorado. This State/Federal cooperative effort with the State of Colorado is administered by the Colorado Department of Health through the Grand Junction Area Office. The remedial action provides for removal of uranium mill tailings from the premises of about 626 structures where radon daughter exposures exceed the Surgeon General's guidelines. Public Law 95-236 extended the time for property owners to apply for inclusion in the program (which has now expired), and increased authorized program funding. Federal funds cover 75 percent of the program costs with the State providing the balance.
FY 1985 is expected to be the last year Federal funds will be requested for the program. The Grand Junction Office administers this program. Through FY 1982, work had been undertaken at 472 structures including 400 residences, 12 schools, and 60 nonresidential structures. In FY 1983 the program will continue with radiological assessments and will initiate remedial actions at about 70 structures. In FY 1984, the program will complete remedial actions on 70 structures for a total of 612 structures out of a total of 626 to be completed.

Uranium Mill Tailings

The Uranium Mill Tailings Remedial Action (UMTRA) program is responsible for conducting remedial actions at 24 sites and an estimated 5,000-6,000 vicinity properties mandated by Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978." Nine of the sites are designated as high priority, six as medium priority, and nine as low priority. The Act requires completion of the program within seven years of promulgation of standards by EPA, which were issued in December 1982. An evaluation is now ongoing to assess the feasibility and budget impact of the mandated 7-year schedule. After completion of the evaluation, an amendment to P.L. 95-604 may be offered to extend the period of DOE's authorization so the completion of the project can be accomplished in a more cost effective manner. Remedial actions will be conducted in accordance with cooperative agreements negotiated with the affected States and Indian tribes. Federal funds are to cover 90 percent of the remedial action costs (100 percent for those sites on Indian lands). The type of remedial action for the processing sites will be either to stabilize the mill tailings in-place, where feasible, or to remove the tailings to a new federally-owned disposal site. The program also includes the cleanup of properties in the vicinity of the processing sites which have become contaminated with radioactive material derived from the sites. It is estimated that from 5,000-6,000 vicinity properties--mainly in the Grand Junction area, but not authorized by the Grand Junction program--may be found eligible for cleanup. Engineering plans and environmental documents will be prepared for the cleanup and disposal operations at each site. The concurrences of the Nuclear Regulatory Commission (NRC) and the affected State (or Tribe) are required for each site remedial action plan.

Specific accomplishments planned for the balance of FY 1983 include the continuation of high priority remedial actions at vicinity properties near the Canonsburg, Salt Lake City, and Grand Junction sites and completion of detailed remedial action plans for four high priority sites (Canonsburg, Salt Lake City, Gunnison and Shiprock). In FY 1984, the program will complete NEPA work and initiate remedial action at these four high priority processing sites.

Surplus Facilities

This program provides for the safe management and disposition of the inventory of surplus Department-owned facilities that have been radioactively contaminated from civilian nuclear energy development programs. The decontaminated facilities and sites are returned to other productive use where appropriate. All defense-related DOE facilities are included in the Defense Nuclear Waste Management Budget. About 80 facilities are currently identified under this civilian activity. In addition, the program develops improved methods for decontamination and decommissioning which can be transferred to industry. A long range plan will be completed in FY 1984 to establish an overall schedule and priorities for sites currently in the surplus inventory. The Richland Operations Office has the lead field office role in implementing the program.

In FY 1983, the on-site activities at the Niagara Falls Storage Site will be accelerated with the goal of completing all interim work in early FY 1984. This will complete the impoundment of uranium residues and contaminated soils which are now in exposed or poor storage conditions in a new improved storage area, thereby assuring no further occurrence of off-site contamination and compliance with the State of New York requirements for radioactive effluent control. The engineering, design and planning phases of the Shippingport Decommissioning Project will be completed in FY 1983. The decommissioning operations at the Mound Facility, Ohio in the Plutonium Processing and Research Buildings will be continued, and the removal of the Waste Transfer System will be started. This work is being carried out as part of a joint project with Defense Programs, with total project completion planned for FY 1988 at a total cost of about $64 million. The project will be 50 percent completed at the end of FY 1983.

In FY 1984, interim actions at the high priority Niagara Falls Storage Site will be completed and substantial progress will be made at other high priority sites. The work at the Mound Facility will reach 60 percent completion. The remedial action program will assume responsibility for the Shippingport Atomic Power Station from DOE-Naval Reactors in late 1984 after defueling and shipment of the fuel to Idaho is completed. During the third quarter of FY 1984 a decommissioning contractor will be brought on board to participate with DOE-NR contractors in plant shutdown and maintenance. Preparations for start of the Decommissioning Project will be completed in FY 1985. Current projections are that D&D of the Shippingport plant will take approximately 3 1/2 years and cost approximately $67M.

Field work at the Weldon Spring, Missouri Site will include start of the stabilization test of pit No. 4; a draft environmental impact statement will be completed for the residue storage pits and the quarry; design engineering will be started for long-term actions at this site.

Radiological Survey and Certification Activities

To promote further efficiency, the Radiological Survey and Certification Activity responsibilities relating to the Remedial Action Program were transferred from the Office of the Assistant Secretary for Environment, Safety, and Emergency Preparedness to my office in January 1983. These activities, funded in FY 1983 at $3.7 million, will be absorbed in the Remedial Action Projects.

West Valley Demonstration Project

The objective of the West Valley Project is to demonstrate solidification for disposal of high-level nuclear wastes under the provisions of Public Law 96-368, the "West Valley Demonstration Project Act". The project will carry out integrated production-scale development and demonstration of the treatment of the high-level liquid nuclear wastes at the Western New York Nuclear Center.

Major activities to be performed as part of the project include: (1) necessary decontamination required to prepare existing facilities and equipment at the Center to accommodate the solidification project; (2) removal of the wastes from the underground storage tanks; (3) development, design, construction and operation of systems and necessary supporting facilities for the solidification of the wastes; (4) acquisition of containers for the permanent disposal of the solidified waste; (5) temporary storage and transportation of the solidified waste to an appropriate Federal repository for permanent disposal; (6) decontamination and decommissioning (D&D) of the waste tanks, facilities, hardware, and material used in carrying out the project; and (7) disposal of low-level and transuranic wastes produced from project activities.

The CY 1982 program emphasized site takeover and initiation of project activities. This year the development of definitive solidification and decontainment plans for carrying out the project is receiving priority attention. With the planning, scoping, characterization, and baselining efforts completed in FY 1983, the FY 1984 program will implement these plans with major emphasis in waste solidification development and design, and decontamination and decommissioning.

Our recent major accomplishments in CY 1982 included:

- Site takeover; issued final Environmental Impact Statement, and Record of Decision.
- Made first manned entry into hot cell.
- Inspected and sampled waste storage tanks.

The FY 1983 program includes the following critical activities:

- Complete waste process and form selection.
- Complete solidification conceptual design.
- Complete decontamination of crane room and work plans and procedures for next four hot cells.
- Commence construction of vitrification equipment component test stand.

In FY 1984 we plan to accomplish the following:

- Complete preliminary (Title I) design of high-level waste solidification equipment and facilities.
- Complete procurement of equipment items for waste solidification component test stand.
- Complete decontamination of four hot cells and work plans and procedures for five more hot cells.
- Initiate procurement of LLW/TRU sorting facility and LLW volume reduction equipment.

Low-Level Waste

Public Law 96-573, the Low-Level Radioactive Waste Policy Act, assigned States the responsibility for assuring disposal capacity for commercial low-level radioactive waste (LLW) generated within their borders. The formation of regional compacts to satisfy this responsibility was encouraged by the law. The goal of the Department's LLW program is to assist states in the development of an effective national LLW management system by 1986 and to evaluate this system in terms of operational efficiency by 1988.

During FY 1983, the Program will complete the development of the regional LLW data base, and continue State/regional technical and financial assistance in support of P.L. 96-573.

The LLW program in FY 1984 will primarily provide technical and financial assistance to States and regions to support selection and operation of new LLW disposal facilities by 1986 (primarily through regional compacts).

Waste Treatment

The objective of this program is to develop and demonstrate technologies for the treatment and immobilization of nuclear fuel cycle radioactive wastes in forms acceptable for transportation, storage and ultimate disposal. Specifically, high-level waste, transuranic waste, and sodium contaminated wastes are addressed. Over the years, methods for treating high-level and transuranic wastes have been developed. This program is now focused on determining the long-term reliability and maintainability of improved prototypical waste treatment systems, on testing and selecting acceptable waste forms for storage or permanent disposal in licensed facilities, and on demonstrating the adequacy of these technologies through their application to specific Departmental waste treatment efforts such as those at West Valley and Three Mile Island (TMI). Activities in this program are coordinated with other Departmental efforts related to fuel reprocessing, generation of special wastes, transportation, and terminal isolation of Department and commercial wastes.

In FY 1983, the performance requirements and specifications for high-level (main focus) and transuranic waste forms and their containers will be developed. The adequacy of a glass waste form to meet these performance requirements will be examined. A reference waste form for commercial high-level wastes will be selected. In the waste immobilization area, emphasis will be on the latest technology for waste vitrification, the liquid fed ceramic melter. Improvements will be made in performance of the melter feed, off-gas and waste glass canister treatment systems. Preparation for development and evaluation of a waste form alternative to glass will also be undertaken.

In FY 1984, waste solidification activities will focus on vitrification process controls and quality verification methods for demonstrating that the glass waste products meet the required specifications developed in FY 1983. Specifications for transuranic wastes will be completed in FY 1984, and development of transuranic waste treatment processes will continue in preparation for future demonstration of these techniques on actual wastes. The sodium treatment facility will be converted to handle radioactive materials and will process contaminated sodium from the Experimental Breeder Reactor-II (EBR-II) operations utilizing the system demonstrated in FY 1983. Criteria and guidance for shallow land burial of sodium contaminated wastes will be tested and completed.

Three Mile Island Program

The Three Mile Island (TMI) program is funded under the Converter Reactors program but is managed and will be discussed under the Commercial Waste Management program. The objectives of the TMI program are (1) to acquire information and conduct R&D that will substantially enhance nuclear powerplant safety, reliability, and operation, and (2) to improve the technology and procedures for safely disposing of abnormal nuclear wastes resulting from an accident.

In consonance with the Administration's policy of private sector responsibility for commercial nuclear power activities, the Department's TMI program is limited to research and development that will be of overall value to the development and safety of nuclear power and waste management. Responsibility for the costs of TMI cleanup remains with General Public Utilities (GPU), the owner of the facility.

The TMI activities are being implemented in accordance with a memorandum of understanding by DOE, NRC, the Electric Power Research Institute (EPRI), and GPU. The efforts of GPU are aimed at plant cleanup and recovery. The Department has developed a program work scope that enables obtaining important R&D information that would not otherwise be available from the TMI-2 cleanup effort. The DOE program is being conducted in a manner that avoids delaying the GPU cleanup schedule.

In accordance with a Memoranum of Understanding between the DOE and the Nuclear Regulatory Commission, the Department will acquire unique radioactive waste, including the damaged core, from TMI for research and development and for disposal.

Two subprograms compose the TMI program: the TMI Data Acquisition Program and the TMI Waste Immobilization and Reactor Evaluation Program. The FY 84 budget request for this program is $37 million as compared to $29 million in FY 83.

TMI Data Acquisition Program

The objective of this subprogram is to obtain R&D data of generic value to the safety of light water reactors.

The DOE and EPRI are sharing responsibility and costs for portions of this R&D program. Specifically, the Department is funding data gathering, research and development, and information transfer in the following major areas: instrumentation and electrical equipment survivability, behavior of radioactive products, data system and specimen achieving, and offsite fuel debris examination. EPRI has responsibility for mechanical and structural component reliability, pressure boundary recharacterization, and decontamination and dose reduction associated with the primary coolant system.

During FY 1983, the analysis of the hydrogen burn event in the TMI-2 containment will be completed and the results provided to NRC and industry for use in calibrating their analytical techniques. Technology transfer activities in the instrumentation programs will be emphasized. Techniques to requalify electrical cables in-situ will be developed.

In FY 1984, DOE plans to conduct the in-situ and offsite examination of selected instrumentation and electrical components to ascertain their condition, cause of failure, and features which affect equipment survivability. Data obtained will be used to upgrade standards and guides, resulting in improved equipment for surveillance of nuclear plants. Efforts will continue on analyzing samples to identify how various radioactive isotopes, released within the containment building during the accident, were transported and deposited. These data will be valuable in assessing the existing models for fission product release which are used in nuclear powerplant licensing. Preparation for the offsite examination of fuel debris will be continued but actual examination will not begin until after defueling starts in 1985. The computer data bank system will continue to collect, store and transfer to NRC and industry the data and documentation generated by the Department's program.

TMI Waste Immobilization and Reactor Evaluation

The objectives of this subprogram are: (1) to conduct research and development on immobilization of abnormal reactor waste products, and (2) to examine the TMI-2 reactor and core components in-situ and to support development activities associated with the reactor defueling. The data acquired will provide an improved basis for evaluation of licensing criteria and requirements, analysis of causes and consequences of accidents, and improvement of reliability of the design and operation of LWR's. This program element was initiated in FY 1982.

The waste management and immobilization activities are initially being focused on an effort to demonstrate the feasibility of vitrifying zeolite ion exchange materials. The program will have demonstrated this feasibility in FY 1983.

Beginning in FY 1983 and continuing in FY 1984, this subprogram will focus on other techniques for the treatment of abnormal wastes produced at TMI, including alternative immobilization concepts for inorganic ion exchange zeolites and organic resins, confidence testing and long term sample observation to provide a more extensive data base. Some of the areas which will be addressed include demonstration of liner disposal in a high integrity container, resin solidification and lysimeter testing. The knowledge gained will contribute substantially to the technology for processing and disposing of unique waste forms resulting from abnormal reactor operations and accidents.

The reactor evaluation activities include examination, removal, and disposition of the reactor core and internals. The special systems, equipment, facilities, and processes needed to accomplish the defueling operation, including examinations, tests, and evaluations of the fuel, will be developed.

To date, over 170 manned entries have been made into the reactor to determine both the extent of damage and the resulting program requirements. Principal efforts will be directed to the goal of removing the reactor head late in FY 1983. In parallel, the development and engineering of systems, equipment and procedures for reactor plenum removal and storage and for reactor defueling and fuel transfer will be initiated. In FY 1984, plenum removal will be accomplished and core disassembly activities will begin. Work will be directed toward preparing for a thorough examination of the reactor internals and core and performance of defueling activities in a radiation environment as low as practicable. Substantial beneficial data on the condition of the reactor core and other internal components will be obtained. In addition, preparations will be made for extensive off-site examinations of the fuel, debris and reactor internal components to characterize the accident effects.

This program will provide the data required for evaluating present licensing criteria and requirements; developing future licensing criteria; assessing and developing computer models used to analyze the course and consequences of severe accidents; developing means to mitigate the effects of such accidents; and evaluating improvements to reactor design, operation, and maintenance.

CONVERTER REACTOR SYSTEMS

The overall goals of the Converter Reactor Systems Program are threefold: 1) to improve the efficient and safe use of converter reactors through improvements in Light Water Reactor (LWR) technology, 2) to contribute to the resolution of the nuclear industry's regulatory, financial, and institutional problems, and 3) to fulfill the Federal Government's research and development commitment associated with General Public Utilities' cleanup of Three Mile Island (TMI). In FY 1984, this program will focus on the following activities: 1) the Loss of Fluid Test (LOFT) facility; 2) research and development and information retrieval on TMI; 3) in-house regulatory, financial, and institutional analyses of obstacles to a healthy nuclear-electric industry; 4) coordination of a national LWR safety program; and 5) completion of work on a single LWR fuel design for extended burnup.

The FY 1984 budget request for Converter Reactor Systems is $53.2 million, down from $78.8 million in FY 1983. The following table reflects the breakout of these funding levels.

	(B/A in Millions) FY 1983	FY 1984
Light Water Reactor Systems	$ 10.0	$ 15.0
High Temperature Reactors	35.3	0.0
Three Mile Island Activities	29.0	37.0
Advanced Reactor Systems	4.2	0.0
Program Direction	0.3	1.2

Light Water Reactor Systems

Since FY 1976, the LWR program has been concerned with developing and demonstrating technical advances in the design, manufacture, and operation of LWRs in order to enhance their safe and efficient use as a source of base-load electrical energy. Today, the major problems confronting the nuclear reactor industry are no longer technical, but are institutional, financial, and regulatory in character and as such the FY 1984 Converter Reactor Program places more emphasis on these. The foremost priority in this regard is reform of the current, inefficient NRC licensing process. I will now briefly discuss each of the Converter Reactor Program activities.

Light Water Reactor Institutional and Safety Program

The proposed LWR safety R&D program has been reoriented to provide the technology base needed to support institutional improvements in the way nuclear technology is licensed and regulated. In particular, support for nuclear regulatory reform proposals and for satisfying the requirements of the Nuclear Safety Research, Development, and Demonstration Act of 1980 (Public Law 96-567 - to develop a technical basis to effect improvements in the ability of LWR industry to produce reliable, economic, and safe nuclear power) are provided for in the FY 1984 program plan.

Our objectives pertaining to regulatory reform fall into five major categories. First, approval of standard designs. This provision would authorize the Nuclear Regulatory Commission (NRC) to approve standard designs for entire plants or subsystems so that utilities have the option of choosing a plant of preapproved design in lieu of one-of-a-kind or customized plant design. The objective is not only a major improvement in both time and dollars required to review, certify, and build a plant to meet the NRC's safety criteria, which will translate into lower costs to consumers, but an enhanced degree of public health and safety due to greater familiarity with the plant during its construction and operation.

Second, advanced site approval. This provision authorizes the NRC to approve sites for prospective nuclear plants in advance of a utility's decision to apply for permission to construct such a plant. The objective is to provide for earlier and more effective public participation in the site selection process before significant funds are expended, thereby reducing unnecessary expenses and costly planning uncertainties.

Third, integrated licensing procedures. This provision permits utilities to apply to the NRC for a construction and operating license in one proceeding in lieu of the current process whereby a construction permit and an operating license are obtained at different stages of the process. The objectives are more meaningful participation for the public, a more systematic and comprehensive review by the NRC, and greater predictability and certainty for utility planners.

Fourth, centralized review of proposed design modifications. This provision requires the NRC to provide for centralized review and approval of all backfitting proposals made by the NRC's staff. The objective is better prioritization and more logical sequencing of modifications that have been judged to offer significant safety improvement, thereby minimizing wasteful duplication of effort. In addition, criteria would be established which would require a design modification to result in a significant improvement in public health and safety when considered over the life of the plant before it could be incorporated. More attention would be paid to a proper balancing of costs to the consumer of plant backfits, and the potential improvements in their health and safety.

Fifth, improvement in the hearing process. This provision allows legislative hearings for most issues, thereby reserving adjudicatory hearings for contested issues of material fact. It also assures that issues already settled in other proceedings do not have to be reviewed again unless additional material facts are introduced. The objectives are to focus more time and resources of the NRC on substantive public health and safety issues, while at the same time permitting a more effective licensing process.

To satisfy the legislated requirements of the Nuclear Safety Research, Development and Demonstration Act, the Department will coordinate the development and implementation of a DOE/NRC/industry cooperative program to establish the priorities of institutional and technological safety issues and to determine how best to resolve these issues. The first step will be the development of a systematic and integrated approach to LWR safety.

The program is divided into two phases--a program definition phase and a program implementation phase. Program needs and priorities are being defined by utilizing working groups composed of representatives from DOE, NRC, industry, and national laboratories. DOE has convened ten of these working groups. Additionally, the three specific studies required by Public Law 96-567 (A Comprehensive Program Management Plan, The Need and Feasibility of a National Reactor Engineering Simulator, and the Sufficiency of U.S. Efforts to Provide Specially Trained Operators for Nuclear Plants) were submitted to the Congress in FY 1982.

Anticipated accomplishments in FY 1983 include:

- o Continuation of work with utilities to improve plant operators response to accident conditions and ability to restore a plant to a normal operating condition.
- o Completion by the Institute for Nuclear Power Operations (INPO) of job and task analyses for powerplant operators so that improved training programs can be developed for coping with accidents.
- o Continuation of support for and coordination of working groups developing the national safety R&D program as required by P.L. 96-567.

Expected accomplishments in FY 1984 include:

- o Support for the enactment and implementation of licensing and regulatory reform legislation.
- o Development of specific solutions to the institutional and financial problems of nuclear electric utilities.
- o Continued coordination of the national safety R&D program consistent with P.L. 96-567.

Since these activities can be accomplished with internal departmental resources, we are only requesting funding in FY 1984 for personnel positions.

Loss of Fluid Test Program

The LOFT program is an internationally funded activity. In FY 1984, this program will adapt the unique capabilities of the LOFT facility (which otherwise would be lost as current related NRC R&D programs are completed) to provide data necessary to reduce uncertainties in primary and containment system responses to severe transients and accidents. Nine tests are planned over a 3-year period with a final severe test to simulate actual fission product releases from a fuel melting accident. The program will be directed by a consortium of the participants and will rely heavily on input from the nuclear industry. The participation of industry is expected to result in a greater focus on economic as well as safety related improvements. It is estimated that program costs from FY 1983 through FY 1986 will be $93.5 million. Of this amount, $25.0 million is FY 1983 NRC LOFT program funds, $15.0 million is FY 1983 NRC funds related to LOFT decontamination and decommissioning that the NRC has committed but Congress has not yet appropriated, $30.0 million is new DOE program funds, and $23.5 million will be contributed by foreign countries.

LWR Extended Burnup

The Extended Burnup Program through FY 1983 has consisted of: first, major projects conducted by selected electric utility/LWR fuel vendor teams to evaluate the extended burnup performance of specific fuel designs, and secondly, several smaller projects to obtain basic data on extended burnup phenomena needed for design and licensing.

The planned accomplishments for the Extended Burnup program in FY 1983 include: 1) the continuation of efforts to obtain generic design and licensing data and other necessary supporting technology and 2) continuation by utility/vendor teams of major R&D projects on extended burnup in LWRs.

In FY 1984, the basic data effort will be continued using funding still available from prior years' appropriations. One major cost-shared contract with a utility/fuel supplier team will also be continued, but other major contracts will be cancelled. These efforts will complete Government support of this program. Private sector organizations such as the fuel vendors, utilities, and the Electric Power Research Institute will--if sufficient incentives exist--conduct the balance of the previously planned program activities without Government assistance.

Light Water Reactor Radiation Dose Reduction Program

No funds are being requested for this program in FY 1984. The phaseout of ongoing projects is being carried out using funds provided in prior years.

High Temperature Reactor

Due to its advanced developmental status, a commercial plant in operation, and the lack of a compelling reason for a new converter reactor concept at a time when there is no market for proven LWRs, no funding for the High Temperature Gas-Cooled Reactor Program is proposed in FY 1984. The focus of the FY 1983 program will be to continue ongoing technology and conceptual design tasks for the steam cycle/cogeneration configuration of the Lead Plant design.

Application and related design and technology studies of advanced and higher temperature modular reactor systems will also be completed in FY 1983 and data will be retained for potential applications to numerous industries that are presently dependent on fossil energy sources. The program will come to an orderly closeout at the end of FY 1983.

Three Mile Island Activities

This program is discussed under Commercial Waste Management.

NUCLEAR FUEL CYCLE

The Nuclear Fuel Cycle program provides for development and demonstration of advanced technology for reprocessing of irradiated fuels from nuclear power reactors. The program will address the stringent requirements associated with reprocessing Fast Breeder Reactor (FBR) fuels, including the higher thermal and radiation burdens, higher fissile content, sodium contamination, and heavier fuel assembly structures. Advanced development for FBR fuel reprocessing will also be available for use by future LWR fuel reprocessors.

The technical program will focus on development and demonstration of reprocessing technology that will provide for reduced radiation exposure to workers, increased environmental protection, increased reliability, enhanced safeguards, and reduced costs.

In FY 1983, installation and testing of equipment in the Remote Operations and Maintenance Demonstration (ROMD) section of the Integrated Equipment Test (IET) facility--the "cold" prototype equipment test facility at Oak Ridge--will continue to evaluate performance and the ability of the equipment to be maintained remotely. Testing will include the continuous rotary dissolver, centrifugal contactors and manipulators needed for remote operations and maintenance. Also, the Integrated Process Demonstration (IPD) section of IET will be put into service. Support efforts will also proceed on instrumentation and control, analytical chemistry, environmental protection, radiation protection, safety and safeguards.

In FY 1984, development of critical components and systems that are to be remotely operable and maintainable will continue. The fuel disassembly and shear machine will be installed and undergo tests in ROMD. Testing of the industrial standard manipulator will continue and testing of an advanced design will be initiated. Conceptual design studies initiated in FY 82 will be continued, and engineering support in IET started, to examine alternative means of developing and demonstrating in a prototypic hot operational environment the necessary breeder reprocessing technology.

Efforts in FY 1984 will also include providing supporting analysis and evaluation for the LWBR proof-of-breeding demonstration, implementing a program to assure adequate means exist for handling and shipping irradiated breeder fuel, and managing the program (funded by ACDA in FY 84 and beyond) to develop alternate low-enriched fuel system for use in test and research reactors currently operating on highly-enriched uranium fuel.

In addition to R&D efforts, the Department is continuing to analyze the institutional impediments to commercial reprocessing of Light Water Reactor fuels, consistent with the directives in the President's nuclear policy statement of October 8, 1981. We have identified a number of major obstacles and will continue to work towards creating an environment in which private industry can again undertake efforts in commercial reprocessing with acceptable business and technical risks.

ADVANCED NUCLEAR SYSTEMS

The Advanced Nuclear Systems Program supports civilian and military space applications through the development of a range of nuclear power system options. Nuclear power sources have provided the electrical energy for the NASA Pioneer, Viking, and Voyager missions, as well as earlier lunar and earth orbital missions. Since 1961, the United States has launched 22 NASA and military space systems having all or part of their power requirements supplied by nuclear power sources.

The Advanced Nuclear Systems budget request for FY 1984 is $34,105,000, a $4,838,000 decrease from the FY 1983 appropriation. Distribution of the funds for Advanced Nuclear Systems is as follows:

Advanced Nuclear Systems	FY 1983 (in thousands)	FY 1984
Flight Systems Development	$17,170	$14,635
Flight Systems Support	20,792	17,100
Special Applications	0	1,000
Program Direction	981	1,370
Total	$38,943	$34,105

This activity is a direct application of the nuclear expertise within the Department of Energy to support approved United States missions of the National Aeronautics and Space Administration, the Department of Defense, and other Federal users.

In accomplishing the responsibilities and in keeping with related statutory requirements, the Department and its predecessor agencies have, over the years, developed a unique complex of laboratories and personnel dedicated to nuclear space power research and development, with a strong emphasis on working within established safety and environmental guidelines. These laboratories have degrees of expertise in producing special nuclear material, forming the isotope material into the desired chemical and physical state, analyzing the materials, and testing the fueled units. Because of the potential safety concerns associated with the use of special nuclear materials, the Department, its laboratories, and contractors have developed extensive expertise, equipment, and facilities for the safe handling of this material. It is because of these unique nuclear capabilities, plus the attendant health and safety responsibilities that the Department--as did the predecessor agencies--has the overall lead responsibility within the Federal government for the development of nuclear power sources for use in space.

In fiscal year 1984, the major undertaking will continue to be the development of the nuclear isotope power generators for use on the NASA Galileo spacecraft and on the NASA/European Space Agency (ESA) International Solar Polar spacecraft, both planned for launch in 1986.

Another major activity is the continuation of the space nuclear reactor power development program in cooperation with NASA and DOD. The objective of this program is to develop space nuclear reactor power sources capable of producing 100 kilowatts or more of electrical power. NASA missions involving nuclear electric propulsion, space stations, lunar operations, and planetary exploration and DOD applications involving communications, surveillance, electronic jammers, and space command defensive weapons will require power levels in this range.

Technology activities are planned to continue towards development of an Advanced modular isotope thermoelectric generator (MITG). This project will enter into the ground demonstration phase. It is envisioned that this generator, with its significant improvements in modularity and high specific power to weight ratio, will be the cornerstone to support the NASA planetary and DOD missions of the future.

Flight Systems Development

This subprogram element includes the design, development, fabrication, and assembly of the isotope space power converter subsystems for the NASA Galileo and NASA/ESA International Solar Polar spacecraft. Several flight converters are planned to be completed and shipped from General Electric, Valley Forge, Pennsylvania, to the Mound Plant, Miamisburg, Ohio. They will be supported by this subprogram element throughout the flight acceptance tests at the Mound Plant. The electrically heated engineering converter will be operated on a long-term endurance test, and technical support will be provided by General Electric to the Mound Plant on the endurance test of the isotope fueled qualification generator. The Final Safety Analysis Report for Galileo and the Updated Safety Analyses Report for ISPM are planned to be published. The Department is currently renegotiating the Interagency Agreements with NASA to include reimbursable work for both the qualification and flight spare units. NASA currently plans to reimburse the Department for all flight units delivered for the Galileo and ISPM mission.

Under the Space Reactor Development Program, which is funded within this subprogram, it is planned to continue component development and reactor concept design definition efforts. Several component subassemblies of the reactor core and heat pipes will undergo testing and analyses along with appropriate safety analyses and overall reactor core design efforts. Several thermal power levels will be examined to determine what type reactor subsystem warrants further development.

In FY 1983 the following efforts were accomplished:

Heat Pipe Reactor (HPR)

- Reactor design reviewed and refined
- Critical experiment performed
- Preliminary mechanical and thermal analyses performed
- Prototype core heat pipe tested at design conditions
- Materials compatibility tests in progress

- First in-pile experiment designed and approved for insertion into EBR-II in 1983
- Initial safety program plan completed
- Water immersion criticality studies performed

Alternative Concepts

Several study contracts were initiated to identify and evaluate alternative concepts. Final design selection will depend on results of ongoing and planned studies under the Space Reactor Development Program, and on Statements of Operational Needs of user agencies.

In FY 1984 the following activities are planned:

HPR

- Continue reactor design activities
- Continue development of material data base
- Continue development of critical component technology

Alternative Concepts

- Continue to evaluate alternative concepts

Flight Systems Support

This funding element supports fuel form production, encapsulation, heat source component manufacturing and assembly, environmental testing of the fueled flight units, and the overall independent safety and safety testing activities.

In fiscal year 1984, the following activities are planned:

- Conduct heat source assembly, fueling and flight acceptance testing of a Galileo and an ISPM radioisotope thermoelectric generator (Mound Plant).
- Conduct independent safety analyses and safety testing (Los Alamos National Laboratory).
- Conduct independent quality assurance and quality control efforts plus independent technical support activities.

Special Applications

This subprogram covers design and integration studies, development tests on advanced radioisotope thermoelectric generator (RTG) components aimed at extending power system lifetimes and minimizing personnel exposure operations, and analyses of compact nuclear reactor powerplants at the request of the Department of Defense (DOD). These efforts are being conducted for application at various DOD facilities. In addition, general nuclear related studies, assessments, and nuclear training programs are also supported.

In FY 1984, the following activities are planned:

- Support system application studies of terrestrial RTG users by conducting power system trade-offs, integration studies, and performance analyses.
- Evaluate the potential of existing space system RTG technology and designs for applicability to terrestrial uses.
- Develop RTG design concepts for terrestrial applications, considering modularity for varius power levels and the potential environments.
- Evaluate modifications or changes to existing thermoelectric material and converter designs to increase reliability, lifetime, voltage requirements for particular applications, and efficiency.

Senator DOMENICI. Thank you very much. There may be a few written questions that Senators might want to submit. As it turned out, we did not have a way of knowing that the Senate would be in session today in terms of the business end and consequently some Senators who wanted to appear are not here. So, we will keep the record open for a few days and if they have some questions, we would appreciate your answering them as soon as you can.

Good morning, Senator.

Senator MELCHER. Good morning, Mr. Chairman. Thank you for having this hearing.

Senator DOMENICI. We have been sort of delaying things waiting for you to come.

Let me proceed. I have some questions. Dr. Brewer, your testimony, that is your written testimony, you refer to a recent loss of sales of enrichment uranium to—enriched uranium, excuse me, to foreign competitors. And U.S. utilities are actually terminating contracts with you and buying foreign supplies. Do you believe this trend could grow?

Dr. BREWER. I believe, Mr. Chairman, that we can reverse it by more competitive pricing, by reducing costs in the program and by changing our contract, thus granting our customers more flexibility in their year-to-year planning but keeping those customers with us for the life of the plant. We are taking very active steps in that direction.

Also, I think we must proceed swiftly with the existing centrifuge technology and beyond that with the advanced isotope separation process, the AVLIS process, and/or the Set V advanced gas centrifuge process. For example, Mr. Chairman, if we were to retrofit the entire eight buildings of GCEP with Set V centrifuge machines, the capacity for GCEP would go from 8.8 million SWU per year to 26 million SWU per year with a massive reduction in the unit SWU price, as much as down to $40 a SWU. The projected cost from the AVLIS process is similar to the projected Set V costs.

And those are the steps that are required for us to remain competitive.

Senator **Domenici**. You, unless I am mistaken now or quoting you wrongly you tell me, you indicated that enriched uranium of foreign origin were heavily discounted. Do you believe—to me sometimes that means that it is being done.

Dr. **Brewer**. Mr. Chairman, the problem, as you know, is a fall off in reactor orders, which creates a surplus of separative work units [SWU's] or enrichment services. This means that a secondary market is created, a very large excess inventory of SWU's worldwide. And any SWU produced today has to compete with the SWU already produced and in inventory.

So that, basically, is the problem we are facing now. There is a large inventory, worldwide, of separative work units which do not have a home.

Senator **Domenici**. Well, I assume for my questions that follow that that is true, but nonetheless does not this trend pose a serious threat of a security nature to us?

Dr. **Brewer**. It poses a threat, Mr. Chairman, in the potential erosion of our domestic market. As you know, we have had severe reductions in the foreign market. We had a hundred percent of the world market in 1974 and now we have about 30 percent, due to competition from URENCO, EURODIF, and the Russians.

In the past 6 or 9 months, we have seen some erosion in our domestic market—that is to say contracts terminated in favor of contracts with our competitors.

Senator **Domenici**. I understand what we are seeing with the high priced American dollar and overproduction. In many areas we are seeing exactly the same situation. It is not that different from what is happening to copper and the mining industry.

But Mr. Voigt was quoted recently in Forbes, as I remember, and he said if we do not keep this industry viable, we could become as vulnerable in uranium as we are in oil. You did say that, did you not?

Mr. **Voigt**. That is correct, Mr. Chairman.

Senator **Domenici**. You have just given me your explanation of how you are going to keep it from happening, hopefully, with reference to uranium. I wonder if that great concern expressed by Mr. Voigt, it seems to me it must be the opinion of the Department. Is that correct? I mean he is not stating anything that you have not said.

Dr. **Brewer**. No, sir, it is my position and concern and that of the Secretary as well.

Senator **Domenici**. Well, then is it not a little hypocritical to be that concerned about the viability of our enrichment industry and not have the same concern about the uranium industry?

Dr. **Brewer**. We do, Mr. Chairman. We are concerned. As you know, a number of uranium properties have been closed in the past year—about 30 to 40. We feel that the way to turn that around is to turn the entire nuclear option around, to produce more orders and to staunch the cancellations from the pipeline.

Senator **Domenici**. Well, in that regard, let me say that I went through a considerable amount of effort and had a significant amount of help up here on the Hill on that nuclear reg authorization bill to make it very forthright that you are going to have to develop some criteria that are going to be used as measuring sticks for the viability of the uranium industry. So let me ask you a little about that, if you do not mind.

What is the timetable for the promulgation of the viability criteria that were mandated for the NRC authorization bill regarding uranium?

Dr. **Brewer**. The bill, Mr. Chairman, I believe calls for the promulgation of the criteria by this October, and a comprehensive review by the President to be submitted to Congress by January 4, 1984. I would like to call on Mr. Geidl of the Energy Information Administration [EIA], who has responsibility for the viability assessment to add to that, if he would.

Senator **Domenici**. I would be delighted to hear from him. Will you include in your answer some of these issues: Do you have enough money in the 1983 and requested 1984 budget to do that and do you have sufficient staff to do it? I am informed that you might not have; and if you do not, where are you going to get the money?

Mr. **Geidl**. That is correct, Mr. Chairman. We have formulated a plan for the responsibility wherein the Office of Nuclear Energy and EIA have agreed that the responsibility for viability assessment will rest with EIA. We also have made personnel and dollar resource estimates of what it will cost to do this work and we have forwarded that through to our Administrator and to the Secretary for a decision to be made.

So to as the question, "Do we have the resources today?" the answer is no. We have made estimates for what we will need today and what we will need in 1984 and beyond.

Senator **Domenici**. All right. Dr. Brewer, why is not the money there?

Dr. **Brewer**. Mr. Chairman, the money is—I should really let EIA answer the question—the money is not there because——

Senator **Domenici**. Wait a minute. There is nothing in the bill about EIA. The bill says the Department of Energy. You chose to use EIA, which is fine. I am not arguing that point. They are the simulator of facts and the projectors and the like. That is what they were created for back during the oil crisis. But the statute is rather unambiguous that you are supposed to do this.

It would seem to me when you have that kind of statute at a minimum you put in your budget enough money to do what is required. Is it in your budget and you just have not gotten around to fill this request?

Dr. **Brewer**. No, sir, it is not in my budget. I believe EIA has budgeted for it in fiscal year 1984. The funds are not in the continuing resolution for 1983, so it will have to be reprogramed from somewhere in the Department.

Mr. **Geidl**. The fiscal years, 1983 and 1984, those budgets were already submitted by the time the law was enacted. So we have not had an opportunity to submit a request for either funding in fiscal year 1983 or fiscal year 1984.

Senator **Domenici**. Do you have available how much you think is needed to do the job within the time table expressed?

Mr. **Geidl**. Yes, sir. We estimate 10 FTE slots and $1.5 million for a total of $2 million.

Senator **Domenici**. $1.5 to $2 million?

Mr. GEIDL. I mean $1.5 million in contract money; $500,000 in salaries for a total of $2 million.

Senator DOMENICI. While technically, Dr. Brewer, the statute was not signed into law by the President until after you had submitted your internal budgets, the budget was not submitted to Congress as a document until after. I do not expect items of this small amount to be changed in that short period of time.

But I guess what I want from you is assurance that as the Department of Energy, you intend to do everything you can to see that they get money necessary to do their study.

Dr. BREWER. Speaking for the Secretary, Mr. Chairman, I will make that commitment and see that funding from some place in the department is reprogrammed to EIA to get the job done.

Senator DOMENICI. That is not a one-way street. I will commit that I will do my share. I just want to make sure that I am not running upstream, so I appreciate your commitment.

Let me talk a little bit about the space reactor development, which you showed up there on your chart as one of the activities that you were in charge to do for others. I understand that, and commend you, for finally entering into a memorandum of understanding with NASA regarding the space reactor development program. If I read your testimony correctly, you will be evaluating alternative concepts in 1984. How will you do this?

Dr. BREWER. Mr. Chairman, first of all, there will be an attempt to define the mission. The Department of Defense and the NASA cannot at this time define the product that they want or when they want it, how big it is, the power level, the duration of the flight and so on. Their mission definition will occur in the next year or 18 months.

At the same time, we will be doing a number of screening studies, combinations of different reactor concepts for space application. Following that, there will be, we will go into the hardware development stage and the Department of Energy will have responsibility for developing the nuclear energy source system. NASA will have the responsibility for the energy conversion system and that will be the way it will be organized in phase two or phase three.

Senator DOMENICI. After you have got the concept, won't you have to have proposals for design?

Dr. BREWER. Yes, sir. We have proposals for design studies now. We are in the process of merging the two programs, the DOE program and the program which was established a few months ago between NASA and DARPA, the technology for advanced space [TASP] program. We are merging those programs. Contracts will be undertaken in the near future. We do not want to contract, of course, for redundant and duplicate work. So within the next several weeks, as chairman of the SP-100 steering committee, I will began integration of the SP-100 program with the other two agencies.

Senator DOMENICI. I understand that you have gone in your planning, and you should, beyond the proposal for the acquisition of design proposals. There would have to then be a next step which would be to evaluate those designs, I assume.

Dr. BREWER. Yes, assuming of course that the mission is established by the two user agencies.

Senator DOMENICI. Are you far enough along to have made a decision on whether you are going to use a national lab or a contractor to evaluate the designs?

Dr. BREWER. We will be appointing a lead organization to integrate the nuclear work. That organization will be within the jet propulsion laboratory project structure, and under the memorandum of understanding that I just signed the Department of Energy has the authority to name that organization. It will probably be a national laboratory, since the industrial contractors could incur a conflict of interest for later equipment development, were they to undertake this evaluation and integration role. So it will probably be a national laboratory.

Senator DOMENICI. So you clearly do not intend to use a private sector contract to evaluate designs for the reasons you have just indicated.

Dr. BREWER. I think it is unlikely, Mr. Chairman. The industrial contractors that we had in mind as a possibility would probably prefer not to bid on the package; again, because it could involve a conflict of interest if they were to bid on equipment work later.

Senator DOMENICI. They will not have the same conflict if they are part of the proposed design group?

Dr. BREWER. No, sir. Because they will be designing bits and pieces and what we are talking about now is an integrating contractor to do the systems design. That is where one might have a conflict of interest.

Senator DOMENICI. Well, I have no objection to the process that you are going through, especially with your explanation that you do not expect the private sector contractor that may end up bidding doing the final evaluating. But I wonder is not the space reactor development program at Los Alamos far enough along, where it could have been considered rather than going through this entire process?

Dr. BREWER. Yes, sir; it is far along in the conceptual design process, the SP-100 program, the heat pipe reactor concept. It will certainly be a leading candidate for these space power applications. But the difficulty, Mr. Chairman, and I would like to say this again and again and again, is that in the past year, I have had great difficulty in getting the customer or user agencies to tell me what they want and when they want it.

Senator DOMENICI. The customer being whom?

Dr. BREWER. The Defense Department and NASA.

Senator DOMENICI. At least now you are at a point where that is going to evolve.

Dr. BREWER. Yes, sir; we have got a schedule for that to evolve.

Senator DOMENICI. Let me move quickly to one other topic. On uranium mill tailings remedial action, what does the Department estimate the cost of the program to be under the recently announced EPA standards?

Dr. BREWER. We, Mr. Chairman, have done a thorough scrub of that program, a bottoms up estimate with an eye toward saving and Dr. Coffman on my right has achieved a cost reduction from about $540 million to $395 million. Would you like to add something to that?

Senator DOMENICI. Doctor, are these factors, cost factors included in the 1984 budget request? Do they find themselves there?

Dr. COFFMAN. Yes, they are. The spirit of the question, as I heard you ask it, was what are the impacts of the EPA standards on this cost. As you know that standard has been relaxed somewhat in terms of the flux levels and concentrations and so on.

Senator DOMENICI. Yes.

Dr. COFFMAN. And, of course, if the standard did not exist, the cost would be zero. However, our estimate is that the current standard provided some $30 or $40 million of cost savings to our program from the relaxation from the initial draft. With a more relaxed standard, based on what has been discussed, we believe would possibly save as much as $30 to $50 million on the $400 million program.

Senator DOMENICI. What was the original authorized level, rough estimate, that Congress evolved?

Dr. COFFMAN. The rough estimate was somewhere between $300 and $500 million. Our first basic cost estimate, based on the original standard, was $540 million in 1982 dollars.

Senator DOMENICI. And you are down to $395 million?

Dr. COFFMAN. We are down to $395 million in fiscal 1982 dollars and 25 percent of that—I am sorry, 10 percent of that is State funded. So when you take out the contingencies and the State funding, the DOE cost should be about $325 million.

Senator DOMENICI. Your plans now, Dr. Coffman, call for starting work on the site cleanup on the four sites in 1984, if I understand correctly. Is that right?

Dr. COFFMAN. That is basically correct. The two highest priority sites are the Canonsburg site in Pennsylvania and the Salt Lake City site in Utah. And the emphasis on the work will be on those two sites located in populated areas.

Senator DOMENICI. The one in New Mexico is in the four.

Dr. COFFMAN. It is in the high priority sites and it is a principal backup, should we run into any difficulties through litigation or injunction at either of the first two principal sites and we do plan to begin work in 1984.

Senator DOMENICI. You plan to begin work in 1984 but only on two.

Dr. COFFMAN. We are conducting and completing the NEPA work and we are beginning conceptional design on all four sites. The large costs come when you begin moving the dirt and that is supposed to begin toward the end of fiscal year 1984.

Senator DOMENICI. Thank you very much. Senator Melcher.

Senator MELCHER. Thank you. Thank you, Mr. Chairman. The Congress felt it was best to increase the executive level salaries last year. Did your salary go up, Mr. Secretary?

Dr. BREWER. Yes, sir, it did.

Senator MELCHER. Was it pretty much automatically? Did Congress increase the gap pretty much to follow through the salary increase that came along?

Dr. BREWER. I believe so, sir.

Senator MELCHER. Some of these R&D programs were being either cut back or held at the same level. I think it was wise of

Congress to increase the pay at the executive level or some of the people that assist you might not have stayed on. Is that correct?

Dr. **Brewer**. Yes, sir.

Senator **Melcher**. So at the same token the people working on R&D all over the country in universities and private institutions must have to take that too in order to retain, the quality people that do research work for that matter, and the same in industry would be true. All are the same basically.

Dr. **Brewer**. Yes, sir. It is very hard to retain good, high caliber talent without adequate compensation.

Senator **Melcher**. So when we look at R&D that is held at the same amount we are actually looking at less work for the same amount of dollars.

Dr. **Brewer**. Yes, sir. The escalation in salaries and other material involved in R&D all enter the scope of the work.

Senator **Melcher**. In this budget, there are two big items; the first is uranimum enrichment. I think you show that on this projected fiscal year 1983 and fiscal year 1984 that whatever the cost to the Government for uranium enrichment will be refunded by private industry.

Dr. **Brewer**. Yes, sir. You will note that the enrichment outlays are matched by revenues. We do it on a full cost recovery basis.

Senator **Melcher**. For fiscal year 1982, you show $24 plus million?

Dr. **Brewer**. In fiscal year 1983, Mr. Voigt?

Mr. **Voigt**. Senator, for the past 3 years, the entirety of the uranium account has been offset by revenues and in fact——

Senator **Melcher**. What was that figure of $24.6 million that subtracted from that figure?

Mr. **Voigt**. I believe in fiscal year 1983, Senator, that was over and above our revenues.

Senator **Melcher**. We don't quite understand this point. On page 11, I said $24.6 and I think it is $26.2.

Mr. **Voigt**. Yes, sir, that was in fiscal 1983 and that is a negative. In other words, the revenues exceeded our costs, sir.

Senator **Melcher**. Yes, it does show a profit.

Mr. **Voigt**. Yes, sir.

Senator **Melcher**. In fact though, it is not a profit, is it?

Mr. **Voigt**. The negative $26.2 million means that revenues will exceed our budget authority request by $26.2 million. It is not a profit as such.

Senator **Melcher**. But there is a lot of overhead and there are a lot of things that we do not have in there.

Mr. **Voigt**. There are some overhead and imputed interest costs that are not in the budget request, but all of these costs are being recovered in the selling price.

Senator **Melcher**. I do not think we are going to change the policy, whatever it is, and I do not think you are getting how much it costs to heat the headquarters.

Mr. **Voigt**. My complete salary, even the increase, goes into my SWU price.

Senator **Melcher**. It is in there?

Mr. **Voigt**. Yes, indeed, sir.

Senator **Melcher**. Then we will just exempt Dr. Brewer and the rest of those gentlemen. What do you want to build that new plant in Portsmouth for?

Dr. **Brewer**. Mr. Chairman, we are building the plant in Portsmouth in order to retain the market. If we do not build a gas centrifuge plant, we will certainly price ourselves out of business.

Senator **Melcher**. Well, you are a monopoly. You are saying that some of the refiners buy from abroad.

Dr. **Brewer**. Senator, we are not a monopoly. In fact, one of our problems is at the present time, we are beginning to lose some SWU customers to URENCO and EURODIF.

Senator **Melcher**. Is that not foreign?

Dr. **Brewer**. Yes, sir. There is no embargo on imported enrichment services.

Senator **Melcher**. All right. How much are you going to spend in Portsmouth this coming fiscal year?

Dr. **Brewer**. The fiscal year 1984 budget includes $572 million.

Senator **Melcher**. That is $572 million out of a pretty slim budget here. Some people seem to think you could have gotten along without spending $572 million.

Mr. **Voigt**. Senator, again, as Dr. Brewer pointed out, when he said that in the absence of building the gas centrifuge enrichment plant, we will have in effect priced ourselves out of the whole enrichment market.

The reason that the gas centrifuge plant is needed is to replace the high cost defusion plants. They are very power intensive; hence, inasmuch as 50 percent of our separative work charge is power related, replacement is a key factor in our ability to compete in the enrichment market.

Senator **Melcher**. How much are you paying?

Mr. **Voigt**. In the 1984 budget, power, on an average, is about 45 mills per kilowatt-hour.

Senator **Melcher**. And the so-called preference estimate?

Mr. **Voigt**. We buy off the systems at the going rates, minus a 5-percent discount which is in lieu of taxes.

Senator **Melcher**. Well, we have got an aluminum plant down there buying at 29 mills, 30 mills, 31 mills, 32 mills. Why don't you use those?

Mr. **Voigt**. I don't believe they are buying power from TVA at those rates. The DOE contract with TVA is to purchase power off the system at the going rates.

Senator **Melcher**. We have an aluminum plant in our State that buys, I use the term preference, but maybe it would be better to call it a contract price. Do you not use power in those enrichment plants the same way?

Mr. **Voigt**. We use it in the same way, Senator, but it sounds like your State has got a better deal than I am getting from TVA.

Senator **Ford**. Well, that is hydropower.

Senator **Melcher**. A portion of it is hydropower, just like a portion of TVA is hydropower. The aluminum plant in Columbia Falls, Mont., is faced with perhaps having to pay close to 30 mills and in TVA it is around 36. So we have a split yet. I am just wondering, since the electrical power part of it seems to be the reason you want to build a new plant, I am just wondering what you are paying. You are paying well over 40 mills and that is 5 percent.

Mr. Voigt. Again, that is an average, Senator. Considering the total system, TVA has higher rates than EEI and OVEC, our other power suppliers.

Senator Melcher. All right. Of that $572 million that you are spending at Portsmouth in fiscal 1984, when are you going to get the money back through the sale of the enriched uranium?

Mr. Voigt. In fact, Senator, we are getting the money back right now. What we do is price over a 10-year campaign and we are recovering the interest on the capital that is going into the plant as it is incurred. Once the plant becomes operational, then we start recovering the capital investment through depreciation expenses. So, to the extent that these costs occur in the 10-year period, we are recouping them right now on our charge.

Senator Melcher. All right. I will drop that one and let Senator Ford pursue Paducah and the possibility of closing it.

Dr. Brewer, it is our understanding, or at least my understanding, that on the breeder in Clinch River there is going to be some private money put up from the utilities or you are not going to pursue the request for $270 million. Is that correct?

Dr. Brewer. Mr. Chairman, the continuing resolution directs the Department to seek more private funding for the financing of the plant, to seek innovative financing mechanisms and to report those to the Congress on March 15. We have convened the utility task force, which will report to us their findings and we will report the findings to Congress on that date.

Senator Melcher. If it is not forthcoming. First of all, are you speaking about 50-50 contributions?

Dr. Brewer. I would not like to prejudice the results of the task force efforts, Senator. But I will say this, if their findings do not appear viable as a matter of practical fact, it is my belief that the project will not survive this session of Congress.

Senator Melcher. We think the R&D money has been cut way too much for the past couple of years. The need for providing R&D funds will probably come out of some other facets of the budget that the President has proposed. We are going to have to see if there is a possibility of taking that budget figure, especially in other facets of R&D.

We will continue with the proper amount of R&D work. I will be interested in what the report will say on this particular item. Will it be ready for report by March 15?

Dr. Brewer. Yes, sir, it is under preparation. The utility group under Mr. Gordon Corey, former vice president for finance of Commonwealth Edison, is putting the finishing touches on the report, even as we speak, and it will be ready.

Senator Melcher. Thank you very much, Mr. Secretary.

Senator Ford. I don't think I have any questions. Most of them have been covered by the chairman. But do you have a choice, I guess, between Oak Ridge and Paducah as to which one will be closed? What will be the earliest date that a plant will be closed?

Mr. Voigt. Senator, we are not only looking at the Oak Ridge and Paducah plants, but we are looking at the Portsmouth diffusion plant as well.

Senator FORD. It seems to me that the other two are going to be struggling, Paducah and Oak Ridge, compared to Portsmouth.

Mr. VOIGT. Let me tell you this, Senator, we have got long-term power contracts with three power suppliers—TVA, EEI, and OVEC. To be able to get out of the contracts requires that we give them sufficient notice. In the case of TVA, it is 8 years of notice; in the case of EEI, it is a 10-year notice; in the case of OVEC, it is a 5-year notice.

So in the study we are doing, things that have to be factored into the overall economic assessment include the impact upon the community, as well as other factors affecting which of the plants should be shut down. But factored into that approach has to be the efficiencies of the plant. The Paducah plant, for example, is the one that does most of the hard work.

Senator FORD. It is called the workhorse of the group.

Mr. VOIGT. Yes, sir, the workhorse of the group. So that is another factor that will be entered into the overall economic analysis.

Senator FORD. I believe that Edwin Kaiser at Oak Ridge has been making some public statements as relates to these plants. If my memory serves me right, he is talking about the late eighties when one plant is closed.

Mr. VOIGT. Well, again, sir, if you take into consideration the length of the power contracts that I just mentioned, that for TVA, assuming that we were to give notice right now, would be 1991.

Senator FORD. Does TVA have the same period, the length of the contract notice for cancellation as Paducah?

Mr. VOIGT. Paducah, yes, so far as TVA——

Senator FORD. They are both 10?

Mr. VOIGT. Eight years for TVA and 10 years for EEI.

Senator FORD. EEI is 10 and TVA is 8 at the Paducah plant.

Mr. VOIGT. That is correct.

Senator FORD. What kind of committee is formed or have you formed a committee to study the options on which plants are closed?

Mr. VOIGT. A formal committee has not been established. It is being run out of my office and it is utilizing the talents of our Oak Ridge Operations Office as well as some of our principal contractors. Both Union Carbide and Goodyear are involved in the study.

Senator FORD. Do you have an informal group that is beginning to work on it?

Mr. VOIGT. Yes, an informal group. Yes, sir.

Senator FORD. Are those in-house?

Mr. VOIGT. They are all in-house, Senator.

Senator FORD. I read an article, I think, not too long ago that said you might get some political heat if it is a race between Ohio, Kentucky, and Tennessee, and I just want you to remember what Abraham Lincoln said when he was a member of the Republican Party: "I want God on my side, but I have to have Kentucky." [Laughter.]

I just hope that you will factor old Abe Lincoln's thoughts into the informal and formal groups as you begin to discuss and study the closure of the plant.

Mr. Chairman, I thank you for the opportunity to question these witnesses. And I want to say one thing about them, they have been fair and reasonable and responsive to me personally. We may not agree on everything, but I give my admiration for at least their efforts to try and I am very grateful to them. I say that publicly and will say it to them privately or publicly that they have been fair and honorable and made every effort to help in whatever area they could and I just want to say that for the record.

Senator DOMENICI. Thank you very much. Did you have anything further that you would like to add?

Dr. BREWER. No, sir, Senator. We are here to respond to your questions.

Senator DOMENICI. I want to compliment you on your testimony and the way you are managing things. I think you have got it under control and we cannot ask for much more at this point. There is good management and good ideas. We will do our best in the process to cooperate with you and I want to thank you and your staff very much for today's hearing.

The subcommittee will adjourn.

[Whereupon, at 10:45 a.m., the hearing was adjourned subject to the call of the Chair.]

APPENDIX II

Answers to Additional Questions Submitted for the Record From Dr. Brewer

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Department of Energy
Washington, D.C. 20585

April 19, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

Following the March 4, 1983, hearing concerning nuclear energy authorization before the Energy and Natural Resources Subcommittee on Energy Research and Development, you submitted additional questions to Assistant Secretary Shelby Brewer. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bc: Mr. Al Astrin
Committee Staff

Questions for Shelby Brewer from Senator Domenici

Uranium Mill Tailings Remedial Action

1. What does DOE estimate the cost of this program to be under the recently announced EPA standards?

The current estimated total cost based on the final EPA standards is $512M in escalated dollars ($420 M in constant '83 dollars) assuming stabilization-in-place for all sites. This includes remedial action for the Edgemont, SD, vicinity properties. It is not yet clear whether all the sites can be stabilized-in-place. Additional costs of from $3M to $40M per site may be incurred if tailings must be moved to alternate disposal sites.

2. Were these costs factored into your FY 84 request?

Since release of the draft final standards to DOE in the fall of 1982, the requirements of the final EPA standards have been considered in DOE cost estimating and budgeting, including the FY 1984 budget request. DOE is also developing comments to EPA on its proposed rulemaking to apply less restrictive standards to the "low" and "medium" priority sites. This has the potential for some additional cost savings in carrying out remedial action at these sites.

3. Your plans call for the initiation of site cleanup at 4 sites in FY 84. Just what kinds of activities will be undertaken?

The FY 1984 budget narrative identified planned remedial action starts for only three sites: Canonsburg, Salt Lake City, and Shiprock. Current plans call for remedial action to be started at two processing sites in FY 1984. These are Canonsburg and Salt Lake City sites. Start of remedial action at Shiprock is now planned for early FY 1985; the deferral was caused by increases in the estimated costs for property acquisition and mobilization at the Salt Lake City and Canonsburg sites.

At Canonsburg the work during FY 1984 will include erection of security fencing; demolition of the Canon Industrial Park Buildings; preparation of the site, including construction of water treatment facilities, flood control features, and a sedimentation pond; construction of the encapsulation cell liner; and excavation of about 20% of the contaminated material. Estimated cost is $4.0M - $4.5M.

At Salt Lake City the work during FY 1984 will include rerouting of site drainage; rerouting of site sewer system; construction of stormwater detention ponds; construction of water treatment plant; initial site grading and construction of temporary roads; and demolition of buildings. Estimated cost is $3.0M to $3.5M.

During FY 1984 vicinity property remedial actions will continue at Canonsburg, Salt Lake City, Grand Junction, and Edgemont.

Question 1: If the Department believes that the technical risk is sufficiently low to support this program, how can the Department justify continued construction of the Gas Centrifuge Enrichment Plant?

Answer 1: The Department's evaluation of the proposal recommending the acceleration of AVLIS development and deployment was influenced to a large extent by our judgment that sufficient data would be available by FY 1987 to decide on the deployment of the AVLIS technology. The decision to accept the proposal in no way indicates that with the current state of AVLIS technology the risk is sufficiently low to commit to this process. While we expect that the risks of demonstration of the technology are low, that demonstration is only one of the issues that must be faced prior to deployment. Specifically, questions concerning the cost of components, lifetimes of lasers and extractors, and operating costs must be answered before a decision on AVLIS deployment can be made.

It is only if the projected performance, capital and operating parameters are achieved, that the process will have reached the goal of providing enriched uranium at less than $40 per separative work unit. At present, when all the above are considered, the risk of relying on the AVLIS process for future enrichment is too high to justify stopping the construction of GCEP.

Question 2: What are the levels of technical risk associated with this accelerated program for the advanced isotope separation process?

Answer 2: The level of risk associated with the accelerated AVLIS program cannot be quantified at this time. The Department has reasonable confidence that sufficient data will be available in the FY 1987 timeframe for a detailed assessment of the risk. We should point out that the decision concerning the deployment of the AVLIS process will have a greater uncertainty with the accelerated plan than with the previous plans of making such a decision after the operation of a full scale prototype, the Development/Demonstration Module. The new proposal will require some extrapolation; however, we believe that the increased risk associated with a decision to deploy the AVLIS technology is warranted in view of the possibility to accelerate the use of this technology for production by about 3 years.

Question 3: Does the proposal advanced by Lawrence Livermore assume significant support from the special isotope separation program of the Defense Program? If so, how much? Is this level of support realistic? Does it presume the AVLIS process will be chosen by Defense Programs over any other process?

Answer 3: The LLNL/UCC-ND proposal does rely on the use of the Special Isotope Separation Laboratory (SISL) at LLNL which was constructed with Defense Program funds. However, there is sufficient space in the facility for both the AVLIS and SIS Programs. The proposal also assumes that much of the costs for completing the development of the copper vapor laser and construction of the SISL laser system will be borne by the SIS Program. The funds associated with this activity are $160 million spread over 5 years. It is our understanding that, because of the high priority Defense Programs has given the SIS Program, much, if not all, of the funds will be available for the laser work. This would be the case if either the AVLIS Program is chosen for the SIS mission or if the decision on the SIS technology were postponed. Clearly, if AVLIS is not chosen for the SIS mission, then we would have to provide the funds for continued laser development and construction of the SISL laser system.

Question 4:	Please explain why the Subcommittee should not recommend a halt to all construction on the Gas Centrifuge Enrichment Plant while accelerating research into the Set V machines so as to provide an opportunity in the mid-1980's to compare the AVLIS process to the centrifuge process?
Answer 4:	The high cost of enrichment from the existing Gaseous Diffusion Plants has contributed to the loss of 65 percent of the foreign market and is seriously threatening our domestic market. Our current contracts are valued at $100 billion between now and the end of the century. The Gas Centrifuge Enrichment Plant (GCEP), as currently planned with Set III and Set IV centrifuges, will be economically competitive in the world market for enriched uranium services as compared to any other proven process. It is still economic to build GCEP and displace diffusion capacity, despite past funding constraints which slipped GCEP completion from 1988 to 1994 and which significantly increased the project's total estimated cost. Any additional delay in the construction of GCEP will further increase its costs and thus make the DOE separative work price less attractive in the market place. The Advanced Gas Centrifuge (AGC) program offers the possibility of producing even lower cost separative work using Set V machines in GCEP. However, as with AVLIS, the technology is not sufficiently developed and the risk too high to make a decision today on deployment of Set V machines.

Department of Energy
Washington, D.C. 20585

May 2, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy and Natural Resources
Washington, D.C. 20510

Dear Mr. Chairman:

On March 4, 1983, Assistant Secretary Shelby Brewer appeared before the Energy and Natural Resources Subcommittee on Energy Research and Development, to discuss the authorization for nuclear energy.

Following that hearing, you submitted written questions for responses to supplement the record. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bcc: Mr. Al Astrin
Committee Staff

Question 1: The program for development of Set IV and Set V centrifuges consists of improvement of materials and subsystems around a proven concept. AVLIS is, on the other hand, a relatively new concept which has not been demonstrated in an integrated production capacity. Why is it that the development times for both AGC and AVLIS are quoted as the same with the same implied confidence? Is centrifuge improvement as difficult as perfecting the AVLIS process? Why can development, demonstration, design, and verification times be shortened for AVLIS when the ERAB questioned the wisdom of proceeding with less than two AIS processes?

Answer 1: The development time for AVLIS is based upon progress to date and our careful analyses of the substantive efforts remaining to be accomplished. The Set V program has been in effect since January of this year. The schedule that we have developed is based on past experience with other centrifuge development efforts. This experience, and our desire to carry AVLIS and AGC to the equivalent level of attainment in the same time frame, have dictated the preparation of an expedited schedule for the Set V program.

Both the AGC and the AVLIS Programs have developmental tasks that need to be successfully completed. The centrifuge improvement embodied in the new Set V concept is as difficult in its own way as the perfection of the AVLIS process, for two specific reasons. First, the Set V construction materials are new. We do not have the many years of experience in fabricating and operating rotors of these materials that we do with earlier designs. Second, we plan to operate the Set V centrifuge at substantially higher speeds of rotation to take advantage of the marked improvement in separative performance with speed increase. We must, therefore, modify or construct laboratory test stands to permit operation at these higher speeds and conduct the tests necessary to verify acceptable operating parameters.

Answer 1: (continued)

The shortening of the AVLIS development schedule is not related to the ERAB assessment of the overall AIS Program. The schedule compression has been made possible by eliminating the planned Development Module and by conducting other activities in parallel that were initially proposed to be done in series. While these modifications have increased the risk somewhat, it is our engineering judgment that the revised schedule is the most effective balance of risk and development cost to enable early use of AVLIS for commercial-scale uranium enrichment. In much the same way, we are assessing the development sequence for the new Set V gas centrifuge concept, to determine how the schedule may be shortened without introducing undue risk to overall achievement of separative performance goals. For example, it may prove productive to conduct reliability testing of the Set V design in parallel with procurement of production model centrifuges, rather than initiating production after completion of the testing. This shortens the overall development time, but introduces a risk by assuming that reliability testing will not reveal unexpected engineering problems.

Question 2: Please provide a step-by-step development, demonstration, and production capacity schedule for both centrifuge (Set III, Set IV, and Set V) and AVLIS which is in the same generic terms for each, including but not limited to, concept development, prototype development and testing, reliability testing and verification, production demonstration, production design, production readiness, and production capacity in-line.

Answer 2: The development and demonstration cycles for the gas centrifuge designs and AVLIS cannot be compared on a one-for-one basis, for the concepts are inherently different. The gas centrifuge itself is the proof-of-principle vehicle for this approach to enrichment. Once the separative capacity for an individual centrifuge is verified, we can assess overall plant construction from this point of data. The balance of plant equipment, dedicated primarily to process control, instrumentation and handling of uranium hexafluoride does not require substantial departure from state-of-the-art equipment. It is, therefore, relatively easy to size the equipment properly to accommodate process gas flow rates.

The AVLIS process differs from the gas centrifuge technique because more than one key item of equipment will dictate overall plant performance. The laser and the separator subsystem each play an important role in determining overall plant performance. Thus, each such system must be assessed, then integrated into a production unit.

The schedule for the Sets III, IV, and V gas centrifuge differ, since each is at a different stage of development. The Set III gas centrifuge has been qualified for use in the Gas Centrifuge Enrichment Plant (GCEP). Reliability testing has been under way in the Advanced Equipment Test Facility (AETF) since May 1981, and will continue at least through the end of FY 1983. Operational testing has been under way in the Centrifuge Plant Demonstration Facility (CPDF) since August 1982. The CPDF is a multi-centrifuge cascade like the one that will operate in GCEP. Operations experience in the AETF and the CPDF has been excellent, with the Set III centrifuges meeting the separative performance goals singly and in cascade, and providing reliability exceeding that specified for GCEP. Procurement of an initial supply of Set III gas centrifuges was initiated in February 1982. Operation of the first train of Set III gas centrifuges in Process Building No. 1 of GCEP, using uranium hexafluoride process gas, is scheduled to begin during July 1985.

Set IV gas centrifuge hardware and operating conditions are presently being evaluated in a series of individual experiments in full-scale centrifuges. We intend to establish a specific design configuration by the end of 1983. This will incorporate in one gas centrifuge the hardware features and operating conditions we conclude are optimum for Set IV. We plan to initiate long-term reliability testing in mid-FY 1985 in the Advanced Centrifuge Test Facility (ACTF) of thirty Set IV machines. We expect that the results will justify installation of Set IV centrifuges in Process Building No. 3 of GCEP beginning in early 1989. They will also be used as replacements for Set III centrifuges in Process Buildings No. 1 and No. 2 as this becomes necessary.

Availability of Set V gas centrifuges is more difficult to project. The development of the Set V concept was accelerated in January 1983, based in large measure on outstanding success in gas centrifuge technology. The expanded effort springs from a modest study of alternate materials and operational concepts conducted in FY 1981 and FY 1982. A carefully planned Set V study began in FY 1983 and will be completed in FY 1984. It focuses on the fabrication and testing of gas centrifuge rotors. Selected prototype rotors will be constructed and tested under expected plant operating conditions. Associated components, such as centrifuge suspension systems will be developed as the full-scale rotors are being fabricated, to provide the complete centrifuge systems necessary for spin-testing. We expect that attainment of the Set V technology will be demonstrated by 1986/1987. Reliability testing of complete Set V designs could begin about 1989. Production of Set V centrifuges could begin about 1991, for installation in Process Building No. 4 and subsequent buildings of GCEP.

The Department of Energy is carefully reviewing possible options for accelerating the performance evaluations of the Set IV and Set V gas centrifuge designs, to assure earliest possible deployment in GCEP. This includes such considerations as overlapping the reliability testing and ordering of production centrifuges, and estimating the attendant risk thereby introduced. The evaluation of optimum development paths for the Set IV and Set V gas centrifuge designs will be completed by the end of July 1983, including an assessment of the impacts of different availability schedules on the cost of separative work.

The AVLIS process has just entered the engineering development/demonstration phase. The major demonstrations during this phase are designed to unambiguously demonstrate AVLIS process performance at plant scale and to provide a sufficient data base which would bound capital costs for specialized equipment and identify any remaining capital cost uncertainties.

The data base would be generated in separate facilities, each dedicated towards demonstrating a particular segment of AVLIS performance or technology. Since the laser and separator subsystems each play a key role in determining AVLIS performance, these subsystems will be separately assessed over the next four years. The demonstration of AVLIS baseline plant performance requires an integration of these two major subsystems. These performance demonstrations are scheduled for the 1986/1987 timeframe. The necessary equipment to perform this aspect of the technology is in the initial stage of design. The development of the AVLIS process in this manner optimizes equipment and resources without introducing additional risk. If these demonstrations are successful and achieved on schedule, then the commitment could be made for AVLIS to proceed into deployment activities in the late 1980's.

Question 3: What is the estimated cost remaining to arrive at a design which is ready for production for the AGC Program? For AVLIS Program?

Answer 3: The Advanced Gas Centrifuge (AGC) Program consists of efforts to develop and assess the engineering capabilities of advanced gas centrifuge concepts, designated Set V. The Set V gas centrifuge is expected to be capable of greatly increased rotational speed and to provide a factor of 2 to 3 times increase in separative capacity compared with the GCEP baseline, Set III, centrifuge. The present Set V program was initiated in January 1983. The overall development cost (in FY 1984 dollars) is estimated to be approximately $400 million, including reliability testing of the Set V design selected.

The present AVLIS development program is structured to provide data on key subsystems and process performance in the 1986/1987 timeframe which would validate specialized plant equipment designs. Depending on the overall level of process demonstration actually achieved, the AVLIS Program could proceed into the production phase. The projected AVLIS development costs through process demonstration and design verification are about $550 million.

Question 4: What quantity of enrichment has been accomplished with the centrifuge process in the past year? Since process development began? What quantity of enrichment has been accomplished with the AVLIS process in the past year? Since process development began?

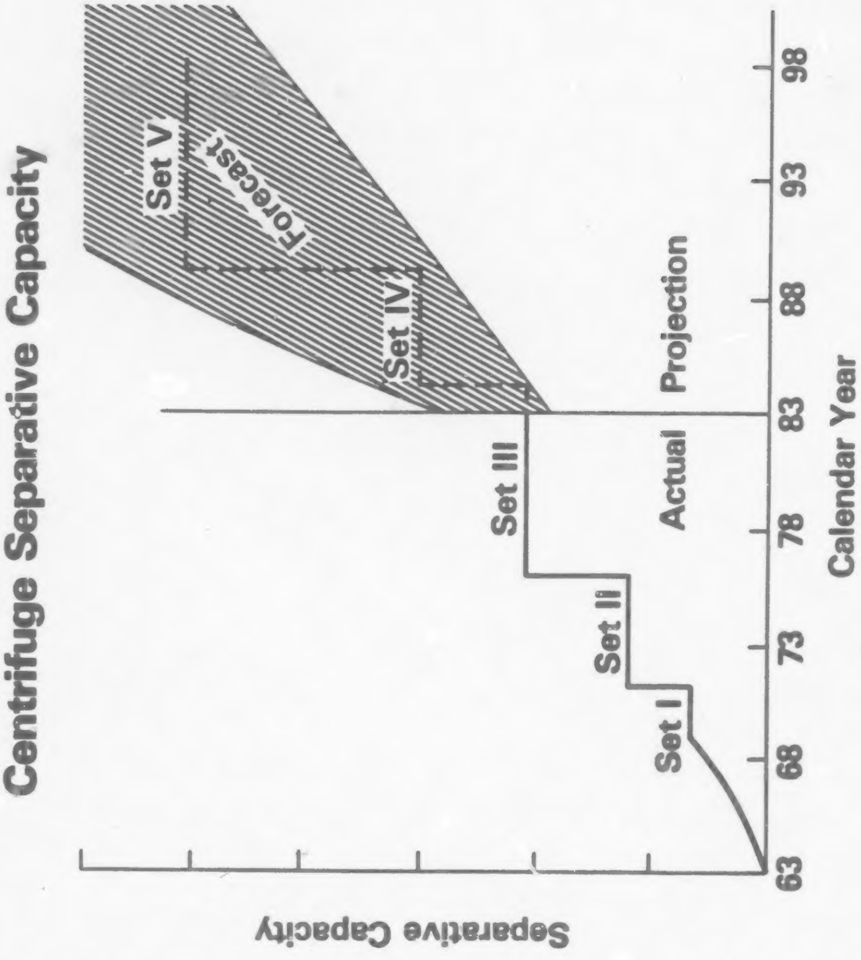
Answer 4: The growth in separative capacity of successive gas centrifuge designs is illustrated in the attached figure. Set III has met the performance goals, while Set IV has achieved 93% of the total separative work desired per centrifuge. We do not expect to verify separative performance of the Set V concept until the FY 1986/1987 timeframe.

The Centrifuge Plant Demonstration Facility (CPDF) has met the unit cascade performance goal established for the Set III centrifuge when deployed in GCEP. It is currently producing enriched uranium at the level of 23,000 separative work units per year. Earlier centrifuge test facilities produced thousands of separative work units per year, although this was not the specific purpose. For example, the Centrifuge Test Facility (CTF) was a major assessment of gas centrifuges in cascade configuration and did produce enriched uranium . However, the intent was to assess cascade operations and determine reliability of selected centrifuge designs. In certain other tests, uranium was enriched for purposes of evaluation, but the enriched and depleted product streams were recombined for recycle.

To date, the AVLIS program has produced a minimal amount of SWU's. The AVLIS Program has been focusing on subsystem development and component development activities in support of the 1986/1987 process demonstrations. At that time, besides the other key features of that process, the AVLIS Program plans to demonstrate baseline enrichment performance in a plant scale system. The reason to delay such a demonstration until full-scale equipment is available is because sufficient laser power is not available and many key AVLIS operating parameters are functions of subsystem geometries. Enrichment experiments performed in sub-scale AVLIS facilities are used primarily to validate designs and confirm scaling relations. Projecting these results to plant scale involves several assumptions which must await experimental confirmation in planned facilities.

Answer 4: (continued)

3.



Question 5: What new facilities and/or equipment must be provided for AGC development prior to production readiness and at what cost? What new facilities and/or equipment must be provided for AVLIS development prior to production readiness and at what cost?

Answer 5: The Department of Energy is presently reviewing facilities requirements for testing the Set V gas centrifuge, including prototype and reliability designs. Existing facilities are being assessed to determine whether they are capable of higher rotational speeds, or may be modified to attain such speeds. We must also assure that any use for testing of Set V centrifuges does not interfere with on-going testing of Set III or Set IV machines.

We are also reviewing the need for new test facilities, in the event present facilities cannot be adequately modified for testing at Set V conditions. One example would be a reliability test facility, where Set V centrifuges may be tested for long-term durability either singly or in cascade configuration. Such a facility, if deemed necessary, would be identified in the FY 1985 budget submission.

No new facilities need to be provided for AVLIS during this development phase. Two major facilities are available to house the AVLIS equipment needed to demonstrate the production readiness of the technology. An existing facility in Oak Ridge, Tennessee, is being modified and upgraded to accommodate a near-plant scale AVLIS separator which has been fabricated. The objectives of the experiments planned in this facility are to develop and demonstrate AVLIS materials handling technology under the thermal conditions envisioned for a production plant. The facility to house the laser system and the AVLIS baseline process performance demonstration has recently been completed at Livermore, California, under the auspices of DOE's Defense Programs (DP). Sufficient floor space is available for both DP and our uranium program needs. The major equipment purchase to be funded by the uranium program consists of the full-scale separator subsystem which includes a plant-like vaporizer and collector array. We project approximately $30 million would be needed for the design and fabrication of this equipment. The cost of the laser system to generate and transmit the light to the separator will be about $75 million. At present, the DP effort in laser separation plans to provide about 75 percent of the funds to construct the laser system. However, if present DP program plans are modified, then we could be faced with an added cost to fabricate and operate the laser system on schedule. At this time, we have provided no contingency in the AVLIS outyear budgets for this possibility.

Question 6: Is the U.S. enrichment enterprise viable without GCEP should AVLIS fail? With GCEP, should both AGC and AVLIS fail?

Answer 6: Without GCEP the U.S. would have only the expensive gaseous diffusion production with resulting higher selling prices. Since price has become the primary factor in the choice of enrichment suppliers additional sales would be lost and the viability of the enrichment enterprise would be threatened. With GCEP, however, we can begin to replace the diffusion plants with the less costly centrifuge production and maintain a competitive price. With a successful AGC or AVLIS program we could realize even greater economics with the probability that our prices would become significantly lower than our competitors.

Question 7: What will the DOE propose in the event of technical or economic failure of AGC and AVLIS?

Answer 7: In this event DOE would propose continuation of the existing approach, that is, completion of GCEP on the current schedule using Set IV centrifuge. The cost of production from Set IV centrifuge is about $61 per SWU as compared to $98 per SWU of diffusion production on an incremental cost basis. Therefore, it would still be advantageous to complete the GCEP in the event both advanced technologies fail.

Question 8:	If AVLIS is significantly less capital intensive than centrifuge, it would be reasonable to expect demonstration facilities to receive similarly less capital. Please compare the CPDF capital costs with those proposed for the Demonstration Module.
Answer 8:	The CPDF is configured to demonstrate a single cascade, the basic unit in a centrifuge plant, which is roughly .3 percent of a full plant in terms of separative performance. The CPDF capital cost is $60 million.

The Development Module (DM) was also designed to demonstrate the performance of a basic unit in an AVLIS plant with first of a kind equipment. Because of the characteristics of the AVLIS process, the separative performance design goal of the DM was 10 percent of a plant. The DM capital cost was estimated to be in the $200-$250 million range.

The AVLIS Program is presently on a development path that ameliorates the need for the DM. Instead of having the DM provide a fully-integrated process performance demonstration by 1989, AVLIS process and technology will be demonstrated in distinct segments in the 1986-1987 timeframe. The capital costs, to be incurred by the uranium program, associated with the revised schedule are projected by AVLIS developers to be $61 Million.

Question 9: How will the Department meet the enrichment requirements for HEU if AVLIS supplants GCEP? What will be the marginal cost for maintaining a GDP to make HEU if the AVLIS capacity is expanded to provide all CEU contract demand?

Answer 9: We have not yet evaluated this in any detail. Assuming that gas centrifuge is not a viable option, the HEU requirements could, of course, conceivably be supplied from new AVLIS type capacity or from existing Portsmouth GDP capacity. AVLIS capacity for HEU production would require significant additional research and development and would be dramatically different from the current AVLIS design for low enriched uranium (LEU) production. We do know that AVLIS becomes less cost efficient when working on a higher U-235 content medium. At this time, however, there are insufficient data to know whether use of AVLIS or GDP capacity would be the most economical. Portsmouth GDP capacity to produce HEU would require annual expenditures of on the order of \$65 to \$70 million in FY 1985 dollars. More specific information is of a classified nature, and we will be happy to provide it on that basis if the Subcommittee so desires.

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

TUESDAY, MARCH 15, 1983

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:34 a.m., in room SD-366, Dirksen Office Building, Hon. Wendell H. Ford, presiding.

Present: Senator Ford.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator FORD. Good morning, ladies and gentlemen. This morning we'll be reviewing the Department of Energy's budget request for fiscal year 1984 in the areas of conservation and renewable energy.

The only witness this morning will be Assistant Secretary Tribble. I would like to invite you to proceed. Your oral statement, Mr. Tribble, and I think we have your written statement, it will be included in the record. You can summarize it as you want to. So you may proceed.

STATEMENT OF HON. JOSEPH J. TRIBBLE, ASSISTANT SECRETARY, CONSERVATION AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY, ACCOMPANIED BY DR. ROBERT SAN MARTIN, DEPUTY ASSISTANT SECRETARY FOR RENEWABLE ENERGY

Mr. TRIBBLE. Thank you, Mr. Chairman. I would like to introduce my compatriot this morning, Dr. Robert San Martin, who is Deputy Assistant Secretary for Renewable Energy.

If my full statement will be included in the record, I have just a few general comments that I would like to make.

The United States energy supply situation is more favorable this year than it was at this time last year. Recent figures indicate that net imports of petroleum into the United States, excluding Strategic Petroleum Reserve imports, are now down to 4 million barrels per day.

Considering the deliveries of petroleum to the United States from Mexico, Venezuela and the North Sea, we as a nation are far less vulnerable to disruptions in the Arab OPEC nations than we were previously. The oversupply of oil is putting pressure on prices, as seen in recent reductions. Second, there are now more than 300 million barrels of oil in the strategic petroleum reserve. Third, efforts to improve efficiency with which energy is used are continuing, and the results of past efforts continue to pay dividends.

These favorable circumstances should in no way minimize the importance of conservation. Falling energy prices put an additional burden on the Department to highlight the importance of continuing conservation and renewable energy programs. As a nation, we should not conclude that short-term changes in prices or supply leads to reduced need for conservation and renewables.

Generally, a timeframe of from 10 to 15 years is required before research finds its way into widespread use. Conservation and renewable energy research which is done now will be very beneficial in the years to come, when the price of energy will surely be higher.

Mr. Chairman, that concludes my general remarks. We would be pleased to attempt to answer your questions.

[The prepared statement of Mr. Tribble follows:]

Testimony of

JOSEPH J. TRIBBLE

Assistant Secretary

Conservation and Renewable Energy

Before the

Subcommittee on Energy Research and Development

of the

Senate Committee on Energy and Natural Resources

March 15, 1983

Authorization - R&D for

Conservation and Renewable Energy

Mr. Chairman and members of the Subcommittee, we welcome the opportunity to meet with you again to discuss the proposals we have made in the FY 1984 budget for Conservation and Renewable Energy programs. In accordance with Congressional direction, the FY 1984 conservation budget is submitted on the basis of end-use sectors rather than the more generic categories which characterized the FY 1983 request. We will cover the details of each of these sectors; however, some general comments are appropriate. First, the U.S. energy-supply situation is even more favorable this year than it was at this time last year. Recent figures indicate that net imports of petroleum into the United States (excluding SPR imports) are now down to 4 million barrels per day. Considering the deliveries of petroleum to the United States from Mexico, Venezuela, and the North Sea, we as a Nation are far less vulnerable to disruptions in the Arab OPEC nations than we were previously. The oversupply of oil is putting pressure on prices, as seen in recent reductions. Second, there are now more than 300 million barrels of oil in the strategic petroleum reserve. Third, efforts to improve the efficiency with which energy is used are continuing, and the results of past efforts continue to pay dividends.

These favorable circumstances should in no way minimize the importance of conservation. As Secretary Hodel has himself stated in testimony, we are well aware of the fact that falling energy prices put an additional burden on the Department to highlight the importance of continuing conservation and renewable energy programs. As a Nation, we ought not to conclude that short-term changes in prices or supply leads to reduced need for conservation and renewables. The Federal Government should provide at least sufficient high-level interest and support for conservation and renewable activities to maintain the momentum achieved thus far. Generally, a time-frame of from 10 to 15 years is required before research finds its way into widespread use. Conservation and renewable energy research which is done now will be very beneficial in the years to come, when the price of energy will surely be higher.

RENEWABLE ENERGY

During the past ten years, numerous technical achievements in innovative energy technologies have contributed to the emergence of a renewable energy industry. Research is still necessary, however, to expand the technology base so that industry can continue to develop and apply these concepts with its own investment capital. The Federal role in this context is to sponsor long-range, high-risk, high-payoff energy research which industry cannot reasonably be expected to exclusively support; and to develop fundamental scientific and engineering knowledge which can provide the basis for new energy developments and the opportunity for increased use of renewable energy.

The budget request submitted to the Subcommittee today represents a continuing commitment to research and development for each technology. These funding proposals were carefully reviewed to ensure that activities to be funded are consistent with the national need. In formulating this request, the Department considered a number of inputs including sources such as the Energy Research Advisory Board (ERAB), Congressional hearings, and discussions with industry representatives.

Four general criteria were used to guide the selection of activities included in this request. First, it should be consistent with the Federal emphasis on long-term, high-risk energy research. Second, the research should add measurably to the technology base. Third, the activity should not duplicate work being performed by the private sector. Finally, the activity should have a high-payoff potential.

SOLAR HEAT

The Solar Heat Technologies program supports R&D activities to provide a technology base which advances the development of thermal materials and which provides a better understanding of thermal sciences.

Previous R&D efforts have provided significant achievements. Experiments with new collector glazing techniques; research on advanced materials; and identification of new technologies to light building interiors show promising cost and performance results. In cooperation with utility partners and the State of California, the Barstow Central Receiver Pilot Plant was completed. This facility is the world's largest solar electric generating plant.

During FY 1983, research is being conducted on high temperature materials and concentrators which can significantly improve the performance and reliability of high temperature collectors and receivers. Research will be performed for second generation heliostats, and high temperature storage components. System studies and conceptual designs will be undertaken to determine the feasibility of central receiver thermochemical hydrogen production. The program will also develop, fabricate and test an advanced dish concentrator for generic thermal electric application.

The Solar Heat Technology program request in FY 1984 totals $21.95 million. This request includes $11.75 million for Materials Research, $7.2 million for Central Receiver Technology, and $3.0 million for Heat Transfer Systems Analysis.

In Materials Research, activities will include test and evaluation of materials with improved thermal tolerances, optical properties and heat transfer characteristics. Thermal-related research will involve the testing of materials to determine their ability to withstand the high temperature and thermal cycling encountered in electric power applications and fuel or chemical production. Research will be conducted to develop new low-cost, high-performance polymer and plastic/metal laminates for low- and medium-temperature collectors. Improved thermal conductivity and dependability in heat transfer materials and fluids with the potential to provide substantial improvements in technical performance and reliability will be investigated.

Central Receiver Technology research will include test and evaluation of components and subsystems at the Central Receiver Test Facility. This activity will provide valuable systems information on the integration of advanced heliostats, receivers and associated controls. Research will also be performed to determine materials and assembly integrity to better define the technical risks associated with adapting the central receiver design to industrial process heat applications. Data collection activities will continue at the Barstow facility to validate operating conditions and system reliability for central receiver power.

Heat Transfer Systems Analysis studies will continue to assess thermal and reliability performance. Specific approaches for using solar technology for interior lighting of buildings without adversely affecting cooling loads will be examined and measured in detail. Research to better understand the process and extent of thermal transport in solar buildings will also be conducted.

PHOTOVOLTAIC ENERGY TECHNOLOGY

The purpose of the Photovoltaic Energy Program is to enhance scientific understanding of the technology and provide a basis for the advancement of photovoltaic systems for both dispersed and centralized electric applications. Research is focused on the characterization of photovoltaic materials and concepts which show promise for improved efficiency, stability and cost.

Important advances have already been made in the photovoltaic technologies. For example, amorphous silicon now offers the potential for ultimately lowering photovoltaic cell costs at high volume production rates. During 1982, laboratory efficiencies of 10 percent were achieved with small area amorphous silicon cells, representing a significant technical advance over the unacceptably low conversion efficiencies previously attained. Through the program, module tests and design algorithms were formulated to stimulate 20-year lifetimes, and the performance of state-of-the-art modules was tested using these techniques. The validation of these accelerated-life tests and algorithms provides a basis for the testing of flat-plate modules to project reliability.

During FY 1983, the effort to develop crystalline silicon photovoltaic cells will near completion. This effort will include the operation and evaluation of a facility which has been designed to produce semiconductor-grade silicon at less than one-half the cost of other methods. Band structure calculations for copper indium diselenide ($CuInSe_2$) thin film photovoltaic cells will be completed this year. Based on this research, a laboratory test cell is expected to show an efficiency of 12 percent.

For FY 1984, the Department is requesting $32.7 million to continue long-range photovoltaic research. This includes $20.5 million for Materials Research, $5.7 million for Cell Theory and Validation Studies, and $6.5 million of Analysis, Testing, and Reliability Studies.

The Materials Research element will include both Thin-Film Materials and Cell Research, and High Efficiency Materials and Cell Research. Since thin-film materials exhibit potential for greatly reducing cell costs, a number of promising thin-film materials and deposition techniques will be characterized and investigated. High efficiency research will emphasize the definition and development of materials and cell concepts with the potential for yielding high conversion efficiencies. These activities include conceptual designs for luminescent devices, the laboratory verification of high concentration Fresnel lens modules, and the characterization of materials for multi-layered cells which may potentially achieve efficiencies of 30 to 50 percent. All of these concepts have shown potential for developing more competitive photovoltaic systems.

In the second major area of research, Cell Theory and Validation Studies, analytical models for predicting and interpreting the performance characteristics of new materials for photovoltaic devices and techniques will be developed. The models should result in an increased scientific understanding of the theoretical framework governing the photovoltaic process and should open the door for identification of additional cell concepts. Cell reliability analyses and tests will be conducted on the conceptual designs, and on sample structures of new cells, to determine potential degradation mechanisms. The results will either confirm the validity of initial designs under consideration or suggest alternatives for future research.

Analysis, Testing and Reliability Studies will be conducted on various mechanical and electrical module configurations to better understand failure mechanisms in cells, modules and arrays. The results of these investigations will be used to determine the requirements for long-lifetime designs of 20 years or more.

BIOMASS

The focus of the Biomass Energy Research program is to establish a technology base for feedstock production and energy conversion for various biomass feedstocks.

Significant research has already been achieved in the area of biomass energy. Production-related efforts achieved yields of 60 dry tons per acre per year of microalgae during a high-density outdoor cultivation experiment. In anaerobic digestion, it was observed that rates of methane production could be increased almost twenty-fold by the addition of selected nutrients.

In FY 1983, production-related research will focus on screening, characterizing, and cultivating promising microalgal species for increased oil production, as well as improving yields of short-rotation woody species through genetic selection and cloning. In conversion, research is being conducted on the mechanisms of thermochemical reactions, anaerobic digestion, and biological hydrogen production. Research activities will also be conducted in alcohol fuels on integrated system designs, gasification and acid hydrolysis of feedstocks. In-situ methane gas generation research and environmental emissions research for energy from municipal waste will be completed in FY 1983.

The FY 1984 budget is $17.3 million. This includes $1.0 million for Production, $12.1 million for Biochemical Conversion, and $4.2 million for Thermochemical Conversion research.

Production R&D will focus on small-scale experiments to screen the capability of various microalgae species to produce measurable quantities of petroleum. The data acquired will be used to select or identify the best species for fuel production from aquatics.

Biochemical Conversion experiments will be conducted on the characteristics of micro-organisms and used to enhance the development of anaerobic digestion, fermentation, and hydrogen conversion processes. These processes offer potential for low-cost liquid and gaseous fuels from renewable resources. Nutritional requirements of anaerobic digesters and pretreatment methods will be examined to determine methods which will increase methane yields, enhance reactor stability, and increase the digestibility of the feedstock.

In Thermochemical Conversion, research will involve the determination of the mechanisms, kinetics, and thermodynamics involved in thermochemical conversion processes. This information is a necessary first step in understanding the fundamentals of advanced thermochemical conversion. Activities will include basic research to improve processes for pyrolysis, direct liquefaction, and gasification of biomass feedstocks.

WIND ENERGY TECHNOLOGY

The Wind Energy Technology program supports research on performance and lifetime characteristics of wind machines for application by the private sectors and develops and validates structural and aerodynamic models to increase the overall understanding of wind as an energy resource.

Several successfully-concluded activities have contributed to the establishment of a wind technology base. Small wind systems research and development performed by the program has resulted in improved machines that help foster the growing small wind industry. In large wind turbine research, initial structural, aerodynamic and environmental tests were conducted at the MOD-2 three-unit cluster at Goodnoe Hills in FY 1982. We believe that large scale wind turbines will eventually lower the cost of electricity in utility applications as compared to small or intermediate sized machines.

In FY 1983, the program will continue its aerodynamic and airfoil technology efforts since there is a need for more research in complex flow regimes and high angles of attack that are unique to wind turbines. To alleviate deficiencies in the wind system related to aerodynamics data accumulated to date, wind tunnel and smoke flow visualization studies are being continued. Success in these research efforts should allow designers to improve performance 20 to 40 percent at certain wind speeds.

The FY 1984 budget request for Wind Energy Technology is $8.6 million. The three major areas of emphasis include $3.6 million for Aerodynamics Research, $3.5 million for Structural Dynamics Research, and $1.5 million for operation of the Small Wind System Test Center at Rocky Flats.

In Aerodynamics Research, the request provides for the refinement of analytical techniques and the development of an understanding of unsteady aerodynamics, particularly the effects of atmospheric turbulence and turbine wakes. Continued development of analytic models based on analyses of experimental data will also be funded, since test results on experimental turbines have shown that performance, wakes, blade stall, and resulting noise are not consistent with current history.

In the Structural Dynamics Research area, further validation of advanced structural models; acquisition of fatigue-life data from Federal and commercial systems; experimental testing of laminar flow blades and advanced airfoils; and investigation of advanced system configurations will be performed for Darrieus vertical axis systems. Atmospheric fluid dynamics research will emphasize the characteristics of wind turbulence and the resulting effect on turbine aeroelastics. Current ability to predict natural frequencies and structural loads is not adequate to analyze the structural dynamics of advanced wind turbines, particularly new turbines with variable rotor speed.

The third area of emphasis is operation of Rocky Flats Small Wind System Test Center. The request provides for research testing and operation of the Center for fee-paid testing services to small turbine manufacturers, utility companies, universities, and research laboratories.

GEOTHERMAL

The long-range direction of the Geothermal Energy program is to emphasize activities that will reduce the technical risk associated with exploiting the geothermal resource base. Program activities completed recently include connection of the deep hot dry rock wells at Fenton Hill; the development of improved geothermal drilling systems; and the completion of short term testing of geothermal resource characteristics at various sites.

In FY 1983, construction will begin on the 50 megawatt binary-cycle plant at Heber, California. Support will also be provided to complete the flow-testing of geopressured design wells; begin operation of the interim hot dry rock loop; improve techniques to estimate reservoir capacity; and to continue the development of geothermal energy conversion technology.

The FY 1984 budget request is $13.5 million. The budget includes $5 million for Hot Dry Rock research; $4.4 million for Hydrothermal research; $2.6 million for Hard Rock Penetration research; $0.8 million for Magma Energy Extraction research; $0.1 million for Geothermal Technology Transfer; and $0.5 million for Program Direction.

The Hot Dry Rock element will focus on completion of the Phase II thermal loop at Fenton Hill, New Mexico, which will provide a deep-fractured system for heat extraction. The Phase II loop will be operated for an extended period to assess reservoir longevity, operating performance, and environmental effects.

Hydrothermal research efforts will address brine injection technology, reservoir definition, and heat cycle research. Brine injection technology development is required for extending reservoir life and for the disposal of spent brines in an environmentally acceptable manner. Heat cycle research will involve the development of second-generation binary-cycle systems required for the generation of electricity from low-temperature hydrothermal resources.

Hard Rock Penetration research will concentrate on fundamental technical problems related to severe downhole drilling conditions. The program will study the mechanics of rock penetration, borehole mapping, drilling instrumentation and data transmission, and the use of high temperature polymers for fluid loss control. In FY 1984, the Geothermal Energy program will take lead responsibility for Magma Energy Extraction research following the successful completion of the energy extraction experiment conducted by the Office of Energy Research. The initial focus of this effort will be to identify the major magma prospects in the United States and then to assess the feasibility of exploiting these resources.

In Geothermal Technology Transfer, results of agency-sponsored research and development will be made available to scientists, engineers, industrial users, educators, and other decisionmakers to foster the utilization of geothermal technology.

GEOTHERMAL RESOURCE DEVELOPMENT FUND

The Geothermal Resource Development Fund (GRDF) was established to accelerate the development and utilization of geothermal energy by promoting competition and encouraging new entrants into the market.

The FY 1984 budget request for the GRDF is $2.1 million. The funds will be used for interest-differential payments and program direction.

Let me turn now to Conservation Research and Development.

BUILDINGS SYSTEMS RESEARCH AND DEVELOPMENT

Since FY 1977, and through FY 1983, the Federal Government has spent $120 million on research for improving the energy efficiency of buildings. This research, combined with the base of information available prior to that time, has brought the state-of-the-art to the point where buildings can indeed be built to withstand severe winter conditions without, or with minimal, heating systems. Virtually every facet of energy use in buildings has been studied. The thermal performance of wall and roof systems has been studied in calibrated hot boxes. Fenestration arrangement and design has been carefully studied, as has ventilation, infiltration and energy management control systems. Sophisticated computer programs have been established for determining energy use in buildings. Many whole buildings have been fully instrumented in order to determine the effect on energy requirements of a number of external variables, such as wind, sun and siting. The effects of thermal mass and moisture migration have been studied.

This is not to say that additional work need not be done. Early this year, the House Committee on Science and Technology and the Department of Energy jointly sponsored, along with other organizations interested in building energy technology, a workshop to evaluate the current status of the body of knowledge relating to energy use in buildings. Our objective was to determine, among other things, what is being done by the private sector and where there are gaps in our knowledge base that need to be filled. To the extent possible, the work which is done in FY 1983 will be directed toward the recommendations from this workshop. FY 1984 activities will be based on these recommendations, to an even greater extent.

INDUSTRIAL PROGRAMS

Of the three major sectors that use the majority of energy, the industrial sector has, by far, the largest incentive to conserve energy. Dollars saved in the reduction of energy consumption are reflected almost directly in profit. For the ten most energy-intensive industries, the energy consumed per unit of production in 1980 was 17.7 percent below the unit energy consumption in 1972. This improvement continued through 1981, when the improvement was 20.8 percent as compared to 1972. It has been said that industrial research and development is aimed at the short-term only, however, this does not account for such research as that done by the forest products industry, where the payoff is some 30 years away; nor that done in the drug industry, where it may take 10 years to bring a new drug to market; nor that done in the communications industry, where such organizations as the Bell Laboratories have been noted for long-term research. From FY 1977 through FY 1983, the Federal Government will have spent almost a quarter of a billion dollars on industrial energy conservation research and development. The effect of this expenditure has been primarily to accelerate the introduction of innovations which would probably have taken place without Federal participation, although at a later time. This program primarily responds to industry proposals, and of course there are many. An effort is made to select those projects which are generic in nature and will have application to one or more entire industries. The Administration has sought both in FY 1982 and FY 1983 to bring this program to a proper conclusion without additional funding. In anticipation of a request for no funds for FY 1983, most of the projects which were undertaken in FY 1982 were funded to completion. In view of the insistence of the Congress to allocate funds for this program, we have requested $10.6 million for research in FY 1984. With these funds, we would expect to continue work on membrane separation of oxygen for enriching combustion air. We would also go forward with the development of a slagging coal burner which might be used to adapt an oil boiler for burning coal. We would continue the reporting program on industrial energy efficiency and continue R&D on freeze crystallization for improved separation and concentration. This would have application in the food industry and perhaps others.

TRANSPORTATION

The Automotive Gas Turbine program is continuing in FY 1983 with two contracting teams. Both teams now have all-metal engines undergoing tests. At the inception of this program, the plan called for the substitution of ceramic parts for metal parts in the high temperature sections of the turbine. Consequently, there has been a parallel effort in developing ceramic components and the means by which such components could be produced. Both teams have successfully tested ceramic components at low temperatures. Further progress in this program will hinge upon additional successes with ceramics. Ceramic behavior in high temperature, oxidizing environments will have to be determined. Improved methods of joining ceramics with metal will need to be developed. Indeed, it is possible that changes may be required in the composition of the ceramic material which is now being used. It is therefore appropriate that research on ceramics and ceramic components be emphasized, with the automotive engines being used as test beds. We believe that it would be appropriate to fully support only one team in FY 1984, with ceramics development and cost-sharing of ceramic parts in the test engine. We do, however, propose to continue to work with both contractors in ceramics development. We have proposed an expenditure of $12 million in FY 1984 with which to carry out this work.

Another element of this program is heavy-duty transport technology. Turbo-compound waste heat utilization technology has demonstrated an improvement of approximately 9-10 percent over current diesel engine fuel efficiency. Use of an organic rankine bottoming cycle waste heat recovery system has demonstrated approximately a 12 percent increase in fuel efficiency for long-haul trucks. Although both of these modifications do, in fact, improve fuel efficiency, they also add to the cost and complexity of operation, including additional maintenance, and therefore will not be implemented until the economics of their use has improved. Little remains to be done in this program. Work planned for FY 1984 will contribute to the development of ceramic materials, joining methodology, and dispersion-toughened composites. The potential of gas-lubricated piston rings will be investigated. Work will also be done to develop solid lubricants. A total of $2.6 million has been requested for this work.

The development of an automotive Stirling engine is also a part of this program. The MOD I engine design is now a reality and, by the end of FY 1983, it is expected that over 2,000 hours of endurance testing of this machine will have been achieved. Transfer of the technology from Sweden to the United States is essentially complete, as evidenced by Mechanical Technology, Incorporated, having assembled the first U.S.-built MOD I engine. During FY 1983, attempts will be made to improve piston ring seals, the control system and the combustor. In addition, an industry evaluation program is now underway where two engine manufacturers will be supplied with MOD I Stirling engines for testing at their own facilities. We believe that, by the end of FY 1983, sufficient technology development will have been accomplished and adequate test data will be available to permit the automotive industry to make a fully-rational assessment of the potential for the Stirling engine in automotive uses. Consequently, the Department is not requesting funds in the FY 1984 budget for continued development of this engine.

In the Electric Vehicle program, we have advanced to the point where the development of a substantially improved battery is necessary for further progress toward a practical electric vehicle. Consequently, the work which is proposed for FY 1984 is heavily weighted toward the development of better batteries. We have requested $9.5 million for FY 1984 to continue this work. In the Alternative

Fuels program, we have requested $4 million. With this, we would expect to establish the optimum approach to the use of synthetic fuels. We would research advanced techniques for storage of methane on board vehicles, and would complete comparative field performance statistics for vehicles operating on straight methanol fuels.

The need for a high temperature materials laboratory has been discussed for several years. Because the development of materials to withstand stress under higher temperatures is so necessary to the further development of the heat engine industry, it seems appropriate to fund the facility from the Transportation program.

ENERGY CONVERSION AND UTILIZATION TECHNOLOGIES

The Energy Conversion and Utilization Technologies program is one which involves technologies cutting across end-use sectors. We have requested $3 million in FY 1984 for this work. With this, we would go forward with the investigation of combustion phenomenon and make an effort to understand "knock" in engines. Another field which deserves some attention is tribology, which is the study of friction and its elimination or minimization. The use of solid lubricants will be required in many high temperature applications, such as the use of ceramics in engines.

ELECTRIC ENERGY SYSTEMS

The Electric Energy Systems program is concerned with electric field effects, power delivery reliability and systems technology. We have requested $12.6 million for this work in FY 1984. With these funds, we would expect to continue biological research on the potential danger to animals and humans of ultrahigh voltages in transmission systems. We would complete the design verification of the deepwater submarine cable for potential use between islands in Hawaii, and would continue research in solid and gaseous electric materials breakdown mechanisms and fiber optics for power system use. Direct current power transmission has some advantages over alternating current transmission. However, the switchgear for use with high voltage DC lines is not perfected. DOE is exploring means whereby a DC circuit can be fed from more than one source, and power distributed from it to more than one demand.

ENERGY STORAGE TECHNOLOGIES

Storing energy has proven to be an elusive undertaking. From FY 1977 through FY 1983, the Federal Government has spent approximately $335 million on attempts to find a suitable means of storing both mechanical and electrochemical energy. Some progress has been made, of course. However, we are still working on a means to store adequate energy to drive an automobile 100 miles. For FY 1984, we have requested $14.2 million. With these funds, we would expect to continue research on sodium/sulfur batteries, zinc/halogen batteries and aluminum/air batteries. We will also attempt to learn more about the basic interaction between electrodes and electrolytes.

Mr. Chairman, this completes my statement. We will be glad to answer any questions you may have.

Senator FORD. Mr. Tribble, I'm trying to figure out what to do here this morning since I had a different tack from where I'm coming from. If you'll bear with me for just a moment.

Mr. TRIBBLE. Surely.

Senator FORD. You state that energy supply is better this year than it was last year. We all understand why we have a better energy supply: We're at about 70 percent capacity, industrial capacity, and therefore, 30 percent is unused. Therefore, 30 percent of the energy is developing a glut on the market, I guess, because we find OPEC, apparently by the paper this morning, has decided on a price. And are you—do you know whether they've arrived at a production figure or not?

Mr. TRIBBLE. The only thing I know is what I heard on the news, and that was 17.5 million barrels per day for the OPEC organization as an organization, which is, I understand, higher than current demand.

Senator FORD. That should give us—it should depress the market even more, shouldn't it? More oil than——

Mr. TRIBBLE. It would certainly seem to do that, yes.

Senator FORD. We're down to about 10 million barrels a day internationally?

Mr. TRIBBLE. I'm sorry, I don't know that number. We are importing on the order of 4 million barrels a day, excluding SPR, and the majority of that is not coming from Arab OPEC nations.

Senator FORD. On page 1 of your statement you said:

> As a nation, we ought not to conclude that short-term changes in prices or supply leads to reduced need for conservation and renewables. The Federal Government should provide at least sufficient high-level interest and support for conservation and renewable activities to maintain the momentum acheived thus far.'

Are you maintaining the momentum achieved thus far when you propose to cut the solar budget I believe somewhere near 60 percent? Cut the geothermal budget almost 75 percent? And cut the conservation budget nearly 50 percent?

Mr. TRIBBLE. These reductions are largely the result of two factors: One is that we are no longer doing demonstration activities, we are no longing buying and building hardware. That is a very expensive way of demonstrating that known technologies do, in fact, work.

We are trying now to redirect that effort toward research. And our objectives are to work closely with the industries involved, determine where there are gaps in research that need to be filled, and do that research if it is in the national interest.

The program that we have proposed, in our judgment, does that. It continues research in these various areas so that we can provide a broadened knowledge base that the private sector can use in generating additional conservation for the years to come.

There's one thing that I would like to mention relative to the reduction in use of oil and the conservation that has taken place. Certainly part of the reduction had been because of the reduced economic activity. On the other hand, there has been substantial improvement in the three primary sectors of energy use—buildings, transportation, and industry—that are not related to lowered economic conditions but are rather reductions in energy per unit of production.

And, for example, the 10 most energy intensive industries have reduced on the order of 20 percent per unit of production since 1972. In transportation, the miles per gallon of new automobiles going into the fleet has approximately doubled. And in the building sector, the energy used, either on the basis of a per square foot per degree day or per household, has been reduced on the order of 15 percent.

We think these trends will continue. The conservation measures that have been taken will continue to pay dividends. And we would hope to see the energy consumption requirements continue to come down.

Senator FORD. It's very difficult for me to see how you can maintain the momentum in the economy as a whole in conservation and renewable energies without, you know, just speculating on what the private sector's going to do. I found that every time you depend on the private sector they still are back here trying to get some help. And that help is not forthcoming.

I find that we normally react. The representative of Saudi Arabia has talked about prices would go back up in 3 or 4 weeks, I think, on TV last night. That always gets us to the point where we react to everything. Statements have been made coming out of the Department of Energy that "based on the energy situation at this time," well, we found ourselves, based on the energy situation at the time of embargo, shortages, high prices, everybody doing everything they could to try to offset it. Then we find that it starts coming down and we relax and say—let the private sector do it. You know, they can do it. We don't need to do anything.

Where I find myself is in the position that at a time when prices are down then it seems to be the time to start to continue to do things. Your budget for research and development area of fusion and fission is about 84 percent of the total amount of money, where fossil fuel research and development is about 7 percent.

So we see a trend there rather than that resource you can reach out and touch, we try to find something else. Like the fellow said down home one time, he said, "I don't understand all I know about this."

So I don't understand why we begin to move away from everything Government leadership ought to give. Do you have any feeling about that? Or are you just being instructed by the OMB on what to do? It seems like they're running the Government instead of the people that were appointed to run the departments, anyhow.

Mr. TRIBBLE. No, we really feel that this is a time that we need to reemphasize conservation. And we need to go forward with the renewable prograns that we have that we think will make a material contribution toward reducing our imported fuel requirements. We realize that this may be a short-term situation that we're faced with, but most of the research that we are doing now is not going to bear fruit within the next 2 or 3 years. We feel that it will be helpful and valuable to us when the time comes that energy prices will be back up.

We do want to continue the development of the use of renewables. And we want to continue to find ways to effect more and more conservation.

Senator **Ford**. Well, in your prepared statement you say that the administration sought in prior years to halt funding for the industrial conservation program but, and I quote, "in view of the insistence of the Congress to allocate funds for this program we have requested $10.6 million for research in fiscal year 1984."

Does that mean, then, that you believe there is no need for an industrial conservation program apart from congressional insistence that there be one?

Mr. **Tribble**. Yes, I personally believe that, Mr. Chairman. I was in industry for 35 years and I have seen the effect of conservation. That was my business for the last 7 years that I was in industry. And I know that, in any energy-intensive industry, any dollars that you save in energy drops right down to the bottom line as a profit. And the industrial sector has ample incentive to do those things that will, in fact, produce that result.

And the fact that the energy consumption per unit of production has come down by 20 percent in the last 10 years in response to high prices and the perception of still higher prices, is adequate incentive for the industrial sector. And while there are some things, certainly, that industry would like to have the Government do for them, in most instances those are projects that the industry will undertake themselves when it is in their economic interest to do so.

Senator **Ford**. Well, you state that you will go forward with the development of a slagging coal burner which might be used to adapt an oil burner for burning coal.

Mr. **Tribble**. Right.

Senator **Ford**. If you didn't do this research would industry do it?

Mr. **Tribble**. They have some incentive to do so because there are, as you know, a lot of boilers that are designed to burn natural gas or oil. And they cannot burn coal without a substantial redesign.

On the other hand, if a burner can be developed which will permit the burning of coal without the passing of the ash up into the boiler sections, then the owners, of this equipment have the availability of fuel flexibility.

As you know, the price of coal is now considerably less than the price of either natural gas or oil. And the owners, particularly with prices escalating as they have done in the last few years, of those boilers that were designed for either gas or oil, do have an incentive to provide the ability to burn coal. The manufacturers of coal-burning equipment have the incentive because, if they can develop such a system, they will be able to sell it to those people who need it.

Senator **Ford**. Mr. Tribble, I asked the question though, if you didn't do this research would industry do it?

Mr. **Tribble**. I feel that they would.

Senator **Ford**. Who in industry and when will they get to it?

Mr. **Tribble**. The boiler manufacturers, the major boiler manufacturers.

Senator **Ford**. When do you think they'll get to it?

Mr. **Tribble**. I think they're working on it now.

Senator **Ford**. You think they're working on it?

Mr. TRIBBLE. Yes. As a matter of fact, some of the burner manufacturers would be interested in it.

Senator FORD. You're zeroing several programs in this budget. One is alcohol fuels, ocean thermal, geopressurized resources. Aren't the last two, the ocean thermal, geopressurized resources, long-term, high risk, high payoff programs that has been the statement of the Department that this is where you want to do your research? Then you're zeroing both of those?

Mr. TRIBBLE. There are good reasons for both of those and I would like to discuss them in detail. First, take the OTEC. We have financed the——

Senator FORD. Is that so-called mini-OTEC?

Mr. TRIBBLE. Mini-OTEC was the pilot plant.

Senator FORD. Yes.

Mr. TRIBBLE. It was the original pilot plant.

We have, with 1982 and 1983 dollars, I believe, gone forward with a conceptual design of a 40-megawatt plant. We also have money in the 1983 budget to go forward with the preliminary design of a 40-megawatt plant. And in a meeting about a year ago, the representatives of all of the various industrial groups that are interested in an OTEC powerplant stated to us that, if we would carry the design through the preliminary stage, they would then pick it up and go from there.

And this is the reason that we have zeroed that for 1984. We will have completed the preliminary design with 1983 funds and do not feel that we need to go further.

The alcohol fuels program is slightly different. We have not zeroed out the alcohol fuels program, but rather have moved it over and for budget reasons included it with the biomass program under the renewable energy side of the house.

We will go forward with research in alcohol fuels designed to generate or to give us a process by which we can economically make ethanol from biomass. This will enable us to to get away from using grain for the production of ethanol. And hopefully we will be able to develop this kind of a process.

Excuse me. Go ahead, Bob.

Mr. SAN MARTIN. If I could just interject, Mr. Chairman. The Congress approved an appropriation for alcohol fuels in fiscal 1983 of $5 million. And what we are requesting in fiscal year 1984 for support of the traditional research and development program in alcohol fuels is an increase from $5 million in 1983 to $8.5 million for next year.

Senator FORD. That's in actual dollars? You all really play on words in this administration. You recommend more than you recommended last year when Congress appropriated a whole lot more. And so really, when you look at it in some respects, you're cutting what was appropriated in 1983 based on your recommendations in 1984.

So I'm going to look at the terminology of the statements very closely. I think on one testimony we had recently, said the agency increased it by $20 million more than they requested last time. And it was $108 that they requested in 1982—or 1983, and about $128, 38 in 1984. Congress appropriated $300 million, so you were really cutting $180 million out of the appropriations of 1983 in the budget of 1984.

It's just like the three-martini lunch; you've got to watch what you say and what it actually means.

Let me ask you this. What are you doing on the problem of indoor air pollution due to residence construction, the so-called "too tight" construction?

Mr. **Tribble**. Let me, if I may, go back to that original question. And I believe the dollars that Dr. San Martin mentioned were appropriated dollars. Is that right?

Mr. **San Martin**. $5 million was appropriated.

Senator **Ford**. I understand that. I just say we have to watch you very closely.

Mr. **Tribble**. Oh, OK. All right, we don't mind.

Senator **Ford**. We have a question before us.

Mr. **Tribble**. On indoor air pollution, we have been doing a great deal of work in the past years. And it has generally been determined that indoor air pollution does not become a problem until the air changes in a building normally get down to on the order of 0.2 to 0.4 air changes per hour.

Generally, most of the ASHRAE standards for buildings codes now in effect require 0.5 air changes per hour. So the codes normally would prevent the closing up of a building to be so tight that this would be a problem. However, we have gone forward with research to develop sensitive, relatively low-cost instruments that will measure indoor pollutants such as radon and formaldehyde.

These problems are very site specific. They are even building specific in the same location. So it is important that there be instruments that could measure these problems. We have done that. We really feel that we have brought this work to the point where it can be handled by the building sector.

One other factor: If there are any health hazards then they should be addressed by EPA and the other organizations that do that kind of work. But from the energy standpoint, we feel that we have carried it to a logical point of conclusion.

Senator **Ford**. Do you think EPA's in the posture of addressing anything right now?

Mr. **Tribble**. Mr. Chairman, I'm not going to get involved in that one.

Senator **Ford**. I'll get you involved in one of yours then.

Mr. **Tribble**. All right. OK. I've got enough in my own house.

Senator **Ford**. What?

Mr. **Tribble**. I've got enough in my own house. I'm not going to get into others.

Senator **Ford**. I understand that. And I'm going to ask you some questions for the record about that, too.

Mr. **Tribble**. All right.

Senator **Ford**. This fiscal year 1982 supplemental appropriations bill created a minimun staffing level of 352 people for the conservation program. You propose a staffing level of 123, I believe. Is that correct?

Mr. **Tribble**. The staffing proposals in the 1984 budget are clearly not adequate to meet the floors nor are they adequate to meet the level of expenditure that we have proposed. They are based on an earlier figure. And we will simply have to say that, after the appropriation is finalized we will make whatever arrangements are needed to get adequate people to operate the programs.

We realize that those are misleading numbers.

Senator **Ford**. Well, so you're taking steps to do whatever to implement the proposed staffing level before you obtain any statutory changes——

Mr. **Tribble**. Yes.

Senator **Ford**. In this mandated staffing provision?

Mr. **Tribble**. Yes, that's right.

Senator **Ford**. Mr. Tribble, there will be some questions for the record that will be sent to you to be answered by my colleagues. I believe that the Congress will revise your budget request—that's my personal opinion—to insure that we, in your words, and I quote them, "maintain the momentum acheived thus far."

There's been some reporting as it related to Dr. Maxine Savitz. And there will be some questions that I will give to you and ask you to answer them for the record.

Mr. **Tribble**. Surely.

Senator **Ford**. And also I will place in the record a copy of the letter that was embargoed that we haven't been able to get a copy of. Somehow or another they float around. So I'm going to put those in the record at this time rather than getting into all that this morning.

[See Appendix III, questions 1 and 2 submitted by Senator Ford.]

Senator **Ford**. I do have about five fairly lengthy questions relating to her and purported violations of the Merit System.

So I'll put those in the record.

There will be other questions from members of the committee.

Mr. **Tribble**. Mr. Chairman, if the committee does see fit to put additional money in the budget, we would like very much to work with the subcommittee and with the staff and put that money where we think collectively it will be the most useful.

Senator **Ford**. I think you can plan to do so with the money basically at the 1983 level. That's where my indication is it would come out.

I checked with staff and there appear to be no further questions of you. But still there will be questions to you in writing. I hope you will respond to those expeditiously.

Mr. **Tribble**. Certainly.

[Whereupon, at 10:01 a.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX III

ANSWERS TO ADDITIONAL QUESTIONS SUBMITTED FOR THE RECORD FROM MR. TRIBBLE

JAMES A. MC CLURE, IDAHO, CHAIRMAN
MARK O. HATFIELD, OREG.
LOWELL P. WEICKER, JR., CONN.
PETE V. DOMENICI, N. MEX.
MALCOLM WALLOP, WYO.
JOHN W. WARNER, VA.
FRANK H. MURKOWSKI, ALASKA
DON NICKLES, OKLA.
CHIC HECHT, NEV.
JOHN H. CHAFEE, R.I.
JOHN HEINZ, PA.
J. BENNETT JOHNSTON, LA.
HENRY M. JACKSON, WASH.
DALE BUMPERS, ARK.
WENDELL H. FORD, KY.
HOWARD M. METZENBAUM, OHIO
SPARK M. MATSUNAGA, HAWAII
JOHN MELCHER, MONT.
PAUL E. TSONGAS, MASS.
BILL BRADLEY, N.J.

MICHAEL D. HATHAWAY, STAFF DIRECTOR
CHARLES A. TRABANDT, CHIEF COUNSEL
D. MICHAEL HARVEY, CHIEF COUNSEL FOR THE MINORITY

United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

March 16, 1983

Honorable Joseph J. Tribble
Assistant Secretary for Conservation
and Supply
U. S. Department of Energy
Washington, D. C. 20585

Dear Mr. Tribble:

As a result of the hearing in which you testified before the Subcommittee on Energy Research and Development on March 15, 1983, regarding the President's proposed budget for FY 1984 for the Department of Energy's Conservation and Renewable Energy Programs, I am attaching a set of questions for inclusion in the hearing record.

I would appreciate obtaining the responses to these questions by March 25, 1983.

Sincerely,

Wendell H. Ford

Wendell H. Ford,
Ranking Minority Member
Subcommittee on Energy Research
and Development

WHF:jbg

Minority Questions for Mr. Joseph J. Tribble

1. On March 14, an article appeared in the Washington Post which reported that the special counsel to the Merit Systems Protection Board recommended that Dr. Maxine Savitz be reinstated immediately as Deputy Assistant Secretary of Energy Conservation. Furthermore, he is reported to have said, "We have clearly identified violations of the merit system."

Please describe what the situation is with respect to Dr. Savitz.

2. We understand that the Department refused to provide to either the majority or the minority staff of this Subcommittee a copy of the letter to Secretary Hodel from K. William O' Connor, the Special Counsel to the Merit Systems Protection Board.

We understand that the letter is embargoed. Why is it embargoed?

I would like to insert in the record at this point a copy of the letter which the Department has embargoed.

3. Before reassigning Dr. Savitz you created a new position called the Assistant to the Administrator for Conservation and Renewable Energy in the Western Area Power Administration. In a letter to a member of this Committee, Secretary Edwards described this position as head of "a critical, major program."

Has that critical position been filled? When was it created? How many people have you interviewed for this position?

Have you found a permanent replacement for the position of Deputy Assistant Secretary for Conservation?

What has been accomplished in this unsuccessful attempt to reassign Dr. Savitz?

4. In answers provided for the record for Secretary Hodel's confirmation hearing the following appears:

> "The Administration proposed cutting the budget for Federal energy conservation programs by 97 percent while arguing that the private sector would pick up these programs, and do this research even though the Energy Research Advisory Board on Federal R&D Priorities issued a report that disputed that conclusion. On March 15, 1982, in a hearing before this Committee, Senator Ford asked the Assistant Secretary for Conservation and Renewable Energy, Joseph Tribble, "Mr. Secretary, has the Department conducted any kind of studies or analysis which would justify your position then that the private sector will conduct the research you are cutting?"

Mr. Tribble's response was, "No, we haven't conducted any such studies." Mr. Secretary, before this kind of assertion is made again by DOE, can we see some analysis to back it up?

Answer: I believe strongly that the Committee is entitled to receive more than empty assurances, and, after presenting the FY 1984 budget requests, it is my earnest desire to provide the Committee with information which will furnish rational support for the budget requests."

Where is this information intended to furnish rational support for the budget request, which Secretary Hodel desired to provide the Committee?

5. We have a certified statement you made on November 19, 1982, to an investigator named Gary K. Hamer regarding the events preceding the attempt to reassign Dr. Maxine Savitz:

"I emphasized in the beginning to all of my people that this was a new era and that my job, as I saw it, was to cut the budget for this agency. Every time I proposed a budget cut in her programs I could be certain that I would get at least an hour's argument from her. She never accepted our need to cut back. Others argued, too, concerning the cutbacks, but certainly not the same degree as she did. Even after I made the decisions, she would always try to appeal to me. However, I can recall no specific time when she did not follow instructions and implement the new policies after the final decisions were made." (emphasis added)

Did you make this statement? Do you see your job as entailing anything other than cutting the budget for this agency? What? Is the reason you attempted to reassign her that she did not agree with your philosophy regarding the Federal role in energy conservation?

Department of Energy
Washington, D.C. 20585

April 4, 1983

Honorable Wendell H. Ford
Ranking Minority Member
Subcommittee on Energy Research
and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Senator Ford:

On March 15, 1983, Assistant Secretary Joseph J. Tribble appeared before the Senate Energy and Natural Resources Subcommittee on Energy Research and Development concerning the President's proposed budget for FY 1984 for the Department of Energy's Conservation and Renewable Energy Programs.

Following the hearing, you submitted questions to Assistant Secretary Tribble to be included in the hearing record. Enclosed are the answers to those questions. A copy has been sent to the Committee for inclusion in the record.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius
for
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bc: Mr. Al Astrin
Committee Staff

Question 1. On March 14, an article appeared in the Washington Post which reported that the special counsel to the Merit Systems Protection Board recommeded that Dr. Maxine Savitz be reinstated immediately as Deputy Assistant Secretary of Energy Conservation. Furthermore, he is reported to have said, "We have clearly identified violations of the merit system." Please describe what the situation is with respect to Dr. Savitz.

Answer: The Department has received recommendations transmitted by the Special Counsel, directed to the Secretary of Energy. I have not seen the recommendations, nor do I consider it appropriate at this point that I do so. The Secretary has been asked to review the recommendations and to respond within 30 days. I will of course comply with whatever decision he makes.

Question 2. We understand that the Department refused to provide to either the majority or the minority staff of this Subcommittee a copy of the letter to Secretary Hodel from K. William Connor, the Special Counsel to the Merit Systems Protection Board. We understand that the letter is embargoed. Why is it embargoed? I would like to insert in the record at this point a copy of the letter which the Department has embargoed.

Answer: The decision to embargo such documents does not fall within my purview. However, I am advised by the Department's Office of General Counsel that, in view of the provisions of the Privacy Act, it would not be proper for the Department to furnish the Subcommittee staff with a copy of the letter without a written request from the Chairman.

[The Committee staff contacted Dr. Maxine Savitz, the person who is the subject of the embargoed letter, and determined that she has no objection to its publication. The letter follows:]

OFFICE OF THE SPECIAL COUNSEL
U.S. Merit Systems Protection Board

The Special Counsel

May 17, 1983

The Honorable Donald Paul Hodel
The Secretary of Energy
Department of Energy
Washington, DC 20585

Re: Dr. Maxine Savitz, OSC Number 70-3-00003

Dear Mr. Hodel:

This office has completed its review of your decision in this matter, expressed in your prior letter, to decline to effect the recommended corrective actions which I proposed on March 10, 1983. I have reviewed the entire file in order to prepare to file an appropriate complaint against DOE with the MSPB. I have also reviewed the recent testimony of the executives of your department and the legal memorandum prepared for you by Mr. Fygi of your staff, included in the record of the April 19 hearing before the House Energy Subcommittee.

On the basis of this review, I remain convinced, as I testified on April 19, that prohibited personnel practices were committed in this matter by DOE staff. I remain persuaded that the actions taken to reassign Dr. Savitz constituted a deliberate contrivance which resulted in her constructive discharge. I am also convinced beyond peradventure that DOE staff breached the SES regulations of DOE in the handling of this matter, as set out in my prior letter to you.

However, during the preparation of the complaint against DOE to file with the Board, a new consideration developed.

After the hearing before the House Energy Subcommittee, Dr. Savitz and her attorney contacted my office and asked to meet with me and the Associate Special Counsel for Prosecution before any OSC complaint was filed against DOE in this matter. Their request was granted and we met last week. At the meeting, Dr. Savitz and her attorney advised me that she would not now return to DOE as an SES employee even if corrective actions were ordered by the Board. Further, she and her attorney advised me that she would not return to DOE for even one day to obtain back pay and benefits, if reinstatement were ordered.

Under these circumstances and despite my considered opinion as to the commission of prohibited personnel practices by DOE staff, I am constrained to conclude that there is no meaningful corrective action which the Board could order under 5 U.S.C. § 1206(c)(1)(B). Accordingly, it would be inappropriate and wasteful of the scarce resources of this office for me to proceed to file a complaint for such action.

I am therefore closing our file on this matter.

With respect,

K. William O'Connor

KWOC/lmb

Question 3. Before reassigning Dr. Savitz, you created a new position called the Assistant to the Administrator for Conservation and Renewable Energy in the Western Area Power Administration. In a letter to a member of this Committee, Secretary Edwards described this position as head of a "critical, major program." Has that critical position been filled? When was it created? How many people have you interviewed for this position? Have you found a permanent replacement for the position of Deputy Assistant Secretary for Conservation? What has been accomplished in this unsuccessful attempt to reassign Dr. Savitz?

Answer: The position at Western was created in July 1982. It has not yet been filled. Departmental Senior Executives currently in a surplus status have been referred for the position and have been interviewed. None of these candidates were selected, so Western is in the process of advertising for the position. Since the selection will be made by the Administrator of Western, I have not personally interviewed anyone in connection with this position. We have not yet found a permanent replacement for the position of Deputy Assistant Secretary for Conservation. We hope to do so within the next few months.

Question 4. In answers provided for the record for Secretary Hodel's confirmation hearing the following appears:

> "The Administration proposed cutting the budget for Federal energy conservation programs by 97 percent while arguing that the private sector would pick up these programs, and do this research even though the Energy Research Advisory Board on Federal R&D priorities issued a report that disputed that conclusion. On March 15, 1982, in a hearing before this Committee, Senator Ford asked the Assistant Secretary for Conservation and Renewable Energy, Joseph Tribble, "Mr. Secretary, has the Department conducted any kind of studies or analysis which would justify your position then that the private sector will conduct the research you are cutting?" Mr. Tribble's response was, "No, we haven't conducted any such studies." Mr. Secretary, before this kind of assertion is made again by DOE, can we see some analysis to back it up?
>
> Answer: I believe strongly that the Committee is entitled to receive more than empty assurances, and, after presenting the FY 1984 budget request, it is my earnest desire to provide the Committee with information which will furnish rational support for the budget requests."

Where is this information intended to furnish rational support for the budget request, which Secretary Hodel desired to provide the Committee?

Answer: We are in the process of conducting an informal survey of the efforts underway in the private sector in the area of research and development. I would emphasize that many of the reductions made in the budget relate to completion of prior demonstration and data collection efforts, and to a reordering of priorities toward those with the greatest potential for practical application in the future, rather than simply a determination that the private sector would pick up the R&D and carry it forward. In many areas where the private sector is not picking up the work involved, it is because the technologies are not considered economically attractive when compared to other alternatives.

Question 5. We have a certified statement you made on November 19, 1982, to an investigator named Gary K. Hamer regarding the events preceding the attempt to reassign Dr. Maxine Savitz:

> "I emphasized in the beginning to all of my people that this was a new era and that my job, as I saw it, was to cut the budget for this agency. Every time I proposed a budget cut in her programs, I could be certain that I would get at least an hour's argument from her. She never accepted the need to cut back. Others argued, too, concerning the cutbacks, but certainly not to the same degree as she did. Even after I made the decisions, she would always try to appeal to me. However, I can recal no specific time when she did not follow instructions and implement the new policies after the final decisions were made."

Did you make this statement? Do you see your job as entailing anything other than cutting the budget for this agency? What? Is the reason you attempted to reassign her that she did not agree with your philosophy regarding the Federal role in energy conservation?

Answer: Yes, I made the statement in question. I took the position of Assistant Secretary recognizing the importance of reducing the overall Federal budget. I also felt that the Federal Government had gotten involved in a number of conservation and renewable energy activities which were not the responsibility of the Federal Government. I felt that others could be redirected and made more effective and with less cost. It is in this context that I approached the need to "cut the budget for this agency." Equal recognition is given to the need to continue Federal support in those areas where the private sector is unwilling or unable to conduct relevant R&D, if the technology in question has the potential for contributing significantly to the Nation's energy needs. The decision to reassign Dr. Savitz to the position at Western was based on a determination that she was the best qualified person in DOE/CE to handle the job there and by a recognition that she was experiencing considerable difficulty in carrying out the decisions made by myself in relation to the programs under her purview. I felt unable to effectively manage the activities assigned to me with such grudging support from a key staff manager.

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

MONDAY, MARCH 21, 1983

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room SD-366, Dirksen Office Building, Hon. John W. Warner, presiding.

Present: Senators Warner, Ford, and Melcher.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. JOHN W. WARNER, A U.S. SENATOR FROM THE STATE OF VIRGINIA

Senator **Warner**. The Subcommittee on Energy Research and Development will now convene for the purpose of the oversight hearing on the Department of Energy research and development programs—this particular one, fossil energy.

We will review the administration's request in this area which includes coal, oil, and natural gas. We will be hearing from Assistant Secretary Jan Mares testifying for the Department of Energy, and William Willis, General Manager of the TVA. Is Mr. Willis here, yet?

Mr. **Willis**. Yes, sir.

Senator **Warner**. In view of the recent events in the world energy situation, there is a temptation to say that efforts in fossil fuel R&D are not as critical as they were a few years ago. I personally take the opposite view, that they remain quite critical.

Our imports of oil, as we know, are roughly half what they were 3 years ago. The price of crude oil has fallen. We are indeed fortunate to be able to continue filling the strategic petroleum reserve at less cost, but we must not let these events deter us from going ahead with adequate R&D in fossil fuel.

Remembering the events of 1973 and 1979, I think they are situations which could reoccur. I am told here that we are now recovering only 25 percent of the oil we discover to date which indicates that we need some R&D in that area, so without further comment on my part, I think, it is wise that we proceed right on into the hearing, and there being no one to join me at the moment from other members of the committee, we will now hear from the Secretary.

[The prepared statement of Senator Warner follows:]

Statement of Senator Warner

Good morning ladies and gentlemen. Today we will be reviewing the Administration's request for Fossil Energy Research and Development. This request includes research on coal, oil and natural gas. We will have Assistant Secretary Jan Mares testifying for the Department of Energy and William Willis, General Manager of the Tennessee Valley Authority.

In view of recent events in the world energy situation, it is tempting to say that our efforts in Fossil R&D are not as critical as they were just a few years ago. Our imports of oil are roughly half of what they were just three years ago. The price of crude oil is falling. We are building a significant Strategic Petroleum Reserve. We must not let these accomplishments cloud the memory of 1973 and 1979, however. We must not ignore the fact that we have 300 years of demonstrated reserves of domestic coal that we must be prepared to mine and utilize. We have only been recovering 25 percent of the oil we have discovered to date. The research we will be reviewing today will lead the way to more efficient and varied uses of coal, natural gas and oil.

The Committee has gone on record in support of funding energy research at levels equal to those of last year. The Administration proposes reductions. I support this Committee's position, but I also support some of the Department's efforts to target research into technology for the cleaning of coal and the cleanup of emissions. I also support the Department's proposed increased funding for Acid Rain research and research into the effects of the buildup of CO_2.

Mr. Mares, if you would like to begin, please go ahead.

Senator **Warner**. Mr. Secretary.

Mr. **Mares**. Thank you, Mr. Chairman. Good morning to you and members of the committee.

Senator **Warner**. Mr. Ford——

Senator **Ford**. Yes, Mr. Warner.

Senator **Warner**. I just made an opening statement or two.

Senator **Ford**. I missed it.

Well, I'll tell you, I want you to know this is the second opening statement. We made one at 8 o'clock in a military committee, but go ahead.

[A discussion was held off the record.]

Senator **Warner**. Would you care to make any opening comments? I know you are as deeply concerned as I about the R&D in fossil fuel.

Senator **Ford**. I'll get into the question. Thank you for the opportunity.

Senator **Warner**. You have certainly been one of the strongest advocates of fossil fuel in the whole of the U. S. Senate.

Senator **Ford**. You can put that on the record. And I appreciate the chairman's statement.

Senator **Warner**. It is well deserved, so we will now hear from the Secretary.

Mr. **Mares**. Thank you, Mr. Chairman. Senator Ford, members of the committee, we have submitted to the committee a detailed account of the fossil energy 1984 budget request, and with the chairman's permission, I would ask that the formal statement be placed into the record.

Senator **Warner**. Given.

Mr. **Mares**. Thank you, sir. I have a few opening comments and then I would be pleased to answer questions. My principal deputy, Mr. Donald Bauer, and my Deputy Assistant Secretary for Management, Mr. Jerry Walsh, are seated with me at the table this morning, As is customary, we have members of the fossil energy staff present in the event I am unable to provide sufficiently detailed responses to your questions.

STATEMENT OF HON. JAN W. MARES, ASSISTANT SECRETARY, FOSSIL ENERGY, DEPARTMENT OF ENERGY; ACCOMPANIED BY DONALD BAUER, PRINCIPAL DEPUTY TO THE ASSISTANT SECRETARY, FOSSIL ENERGY; AND JERRY WALSH, DEPUTY ASSISTANT SECRETARY FOR MANAGEMENT

Mr. MARES. To summarize our budget request, Mr. Chairman, let me echo two points Secretary Hodel stressed in his appearance before this committee last month. First, comparing this budget request with the one of a year ago indicates some important trends.

In fossil energy, the funds we are requesting for fiscal year 1984, $138 million, represent a 29 percent increase over the request that we made in 1983. Now, I would also make the same statement as Secretary Hodel. We are well aware that this committee and the Congress as a whole recommended and appropriated considerably more in fiscal year 1983 than is in our current budget.

However, we are attempting to suggest that there is a trend within the entire Department's energy budget to provide a better balance of R&D priorities.

The second point I wanted to stress is that we are prepared to work with the committee in reaching an early consensus of what our funding priorities should be. One of the first things Secretary Hodel stressed when he joined the Department was that for too long we as a Nation have torn ourselves apart over energy issues. Do we need more or less? In this form or that? This debate has extended as well into the R&D aspect of energy.

We wholeheartedly support the President's commitment to reduce budget deficits through tighter reins on Federal spending. This must be done, however, within the context of our proposed funding levels. We are prepared to work with this committee to achieve another core commitment, a bipartisan consensus on the mix of scientific and technological activity that will be the most productive for this Nation. This is critical if we are going to make the most efficient and effective use of those very precious dollars which are entrusted to the Federal Government by our taxpayers.

As a starting point for our specific discussions of the fossil energy budget let me briefly outline the basis for the priorities and funding levels we have proposed in this budget. The emphasis of our program, as it was last year, is on the front end of the technology development path—in basic science, applied research, and for some technologies into the proof of concept stage.

We define basic science as the development of scientific knowledge, including a fundamental understanding of the physical and chemical properties of fossil fuels. Applied research takes us into the broad engineering and physical sciences aspect of specific fossil technologies. At this point we gain a better understanding of processes, applications, or systems, although practical utility may not yet be proven.

Proof of concept is where the technical viability of an energy concept is established. Here one learns enough to establish the basic engineering feasibility of a concept and then to be able to forecast the expected economic and environmental performance standards. These are the factors that permit industry to make the subsequent decisions on whether the concept merits further process development and eventual commercialization.

Now we recognize that all technologies do not follow these precise development steps, but the point we are emphasizing when we describe the evolution of technology in this manner is that the focus of the Federal program is most importantly on the generic aspects of research and development. When we move into the process development and the commercialization stages the Government begins running the risk of inserting itself into the selection of one process over another.

As a process becomes more developed, decisions become increasingly governed by a host of complex market-driven analyses and projections, factors historically not within the expertise of the Government. I would like to include in the record an article that appeared February 18, 1983, in "Science" entitled, "Industrial Innovation: Policy Lessons from American History," which emphasizes the point that the important role for Government to go all the way to commercialization only is where the Government is the consumer of the technology. Where the Government is not the ultimate consumer, it has not been productive for the Government to take things all the way to commercialization.

[The article follows:]

(From Science, February 18, 1983)

Industrial Innovation Policy: Lessons from American History

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Government involvement in the research and development (R & D) process has a long history in this country. As is too often the case, this rich experience has seldom been consulted in policy debates over government programs to stimulate industrial innovation.

Summary. The historical interrelations of government support of R & D and technical change in seven major American industries point to three types of policy that have been successful in the past: (i) government R & D support for technologies in which the government has a strong and direct procurement interest; (ii) decentralized systems of government-supported research in the "generic" area between the basic and the applied; and (iii) a decentralized system of clientele-oriented support for applied R & D. A fourth type of policy, under which the government attempts to "pick winners" in commercial applied R & D, has been a clear-cut failure.

This article is an attempt to identify some of the lessons of past federal R & D policy. It summarizes the conclusions of a study, recently completed at the Center for Science and Technology Policy at New York University, of how such policies have shaped technological change in seven major American industries—semiconductors, computers, aircraft, pharmaceuticals, agriculture, residential construction, and automobiles (*1*). What makes this study unique is its explicitly comparative, cross-industry focus: it was predicated on the hypothesis—amply supported in the resulting case studies—that the kinds of government programs that have shown themselves feasible and effective vary greatly among industrial sectors, depending upon the nature of the governmental involvement and the nature of competition in the industry.

The selection of industries for study was made with an eye toward obtaining a sample with a broad spectrum of characteristics: industries with fragmented as well as with concentrated structures and industries subject to much government intervention and to relatively little. The design of the study was also informed by a desire to attract recognized scholars knowledgeable about the technology in each industry; the prior interests and areas of expertise of these scholars were therefore a factor in the selection of industries. The study was then carried out as a cooperative research effort (*2*).

The Unraveling Consensus

In treating the questions of innovation policy as warranting detailed empirical exploration, we were acknowledging, reluctantly, that the general theoretical analyses and statistical observations of economists provide only limited and incomplete guidance for policy. We are not alone in this perception: the most significant aspect of the recent economic literature on innovation is its progressive inconclusiveness about the appropriate role for government.

It was not always that way. Economic research a decade or more ago had settled on two closely related sets of propositions about industrial innovation. The first of these was that technological change is an important source of productivity growth and, simultaneously, that R & D expenditure is a principal determinant of technological advance. The implication drawn from this was that R & D spending is a kind of "control variable" through which one would affect macroeconomic productivity.

The second set of arguments derived from theoretical rather than statistical work. Economists during the 1950's and '60's developed models in which private firms possessed an inherent tendency to

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"underinvest" in R & D. There were several reasons for this unhappy circumstance: (i) R & D creates knowledge, and knowledge is a "public good" in the sense that the firm cannot fully appropriate to itself the benefits of the knowledge it creates (*3*); (ii) the payoff to R & D is uncertain, and risk-averse firms will therefore wish to do less of it than a (risk-neutral) society would prefer (*4*); and (iii) the fragmented structure of certain industries militates against sufficient R & D spending, the firms being too small to undertake certain kinds of projects (*5*).

Taken together, these sets of arguments strongly supported the notion that the government's role lay in correcting a global problem of inadequate private R & D. But over the last decade the consensus surrounding this conclusion has essentially come undone.

First, and perhaps most important, the experience of the 1970's cast doubt on the presumed tight link between a nation's overall R & D spending and its rate of productivity growth. Although it is true that high rates of R & D spending attended the rapid growth of productivity in the United States, Western Europe, and Japan during the 1950's and '60's, spending for R & D continued to be high in most countries during the ubiquitous slowdown in productivity growth after 1973. Only in the United States and France was the slowdown presaged by a decrease in R & D expenditures, and in both those countries the decrease was almost exclusively in defense and space rather than in civilian areas. Moreover, recent studies of the differences in productivity growth among countries suggests that, even in the 1950's and '60's, the countries with the highest ratio of R & D spending to gross national product—the United States and Britain—had among the lowest rates of productivity growth (*6*).

Part of the message seems to be that it matters where a country is relative to the frontier of technology and productivity. Countries not on the frontier can "play catch up" fairly easily without much R & D spending so long as their rates of physical investment are high. Countries nearer the frontier have to work harder for each percent increase in productivity. This begins to suggest that it is not necessarily to a country's great advantage to be alone on the frontier. There is evidence that, as before World War II, the United States is again benefiting from technological ideas developed elsewhere; and there may be much to recommend a world in which many countries share the technological frontier and therefore share a common economic environment in an interdependent way (*7*).

At the theoretical level, many economists have also begun to believe that the relation between competition and innovative behavior is more than a matter of some tendency to "underinvest" (or even to "overinvest") in R & D. The relationships of innovation to information "externalities," to risk, and to market structure are increasingly seen to be subtle and complex (*8, 9*).

In the first place, the implications for total R & D spending of imperfect appropriability are now understood to be less clear-cut than they once seemed. Economists are coming to realize that, in a world of patents and industrial secrecy, firms in some instances have an incentive to engage in duplicative or near-duplicative R & D in an effort to copy a rival's technology or "invent around" its patents. This at once calls into question the idea that firms necessarily engage in too little R & D; more important, it begins to focus our attention not on the level of R & D but on the types of R & D projects the industry engages in.

The economist's view of the "uncertainty" issues had taken a similar turn. Rather than focusing on the amount of R & D that uncertainty is likely to draw forth, economists are now recognizing that what uncertainty really demands is the exploration of a diverse set of approaches. This way of looking at things suggests that heavy commitments to any one approach are dangerous in the early stages of development of a technology and should be avoided until the uncertainties (both market uncertainties and technological ones) are significantly reduced.

What that suggests in turn is that the focus of the policy issue should shift from R & D levels to the portfolio of R & D projects an industry tends to generate. This entails turning our attention toward the incentive effects of policies and institutional structures and toward considerations of access, secrecy, and information flow. In practice, some kinds of R & D projects will tend to be "underfunded" and some to be "overfunded"; and a simple R & D subsidy is not the sort of policy such a situation demands.

The Case Study Approach

Although many economists are exploring new approaches to the theory of innovation and technical change, analyzing the effects of government policy on industrial innovation must still be seen as largely an empirical problem—which policies have worked, which have not, and why. This was the premise behind our seven industry case studies. One conclusion, which we develop below, is that what the government can do effectively differs from industry to industry. There are nevertheless certain features common to technological change in all industries that should be kept clearly in mind in designing government policies.

One theme that unites the history of technological change is the pervasiveness of uncertainty. Although it takes a form in (say) the pharmaceutical industry very different from that in the commercial aircraft industry, uncertainty seems nevertheless to be endemic. A quick reading of the case studies is enough to dash any supposition that technological change is somehow a cleanly plannable activity. In fact, it is an activity characterized as much by false starts, missed opportunities, and lucky breaks as by brilliant insights and clever strategic decisions. Only in hindsight does the right approach seem obvious; before the fact, it is far from clear which of a bewildering array of options will prove most fruitful or even feasible. Strange as it now seems to us, aviation experts were once divided on the relative merits of the turboprop and turbojet engines as power plants for the aircraft of the future; and the computer industry was by no means unanimous that transistors—or, later, integrated circuits—were to be the technology of the future. Policy must recognize uncertainty as a fact of life, and must not try to repress it or analyze it away.

A second and related universal theme is the importance of detailed knowledge of the technology, of its strengths and weaknesses, and of user needs in guiding the innovation process. In all the case studies, either the producer-provider or the user-demander played a major role in generating and screening technological advances. Whenever major innovation was attempted without access to their knowledge, the results were disastrous. This fact imposes severe constraints on what government can do effectively.

The implications become clear if we consider four general kinds of government support for civilian R & D: (i) programs attendant on government procurement or some other well-defined public objective; (ii) programs to support research on "generic" technologies—research in the gray area between basic scientific research and applied R & D; (iii) programs to support applied R & D in the service of well-defined clientele demands; (iv) programs that insist on "picking winners" in commercial applied R & D. Programs of each sort show up in several guises in the industry case studies.

Procurement-Related R & D

In three of the industries studied—aviation, computers, and semiconductors—the government was heavily involved as a user-demander of the technology. This kind of government involvement has two important policy implications.

The first has to do with the ability of the government to guide R & D effectively. In cases of government procurement for defense, space, or similar clearly defined public projects, the government is itself the user-demander. It thus has knowledge of its own needs and, usually, at least a modicum of expertise in the technology it proposes to use. Motivation and knowledge line up fairly well in such circumstances, and the government is frequently able to sponsor effective R & D on the relevant technology. To the extent that the technology can be easily transferred to commercial application, the result is the well-known "spillover" into civilian technology.

Second, a public belief in the legitimacy of the government's primary mission—defense, for example—smooths the political waters for any related program of government R & D support. In the semiconductor industry the Department of Defense and the National Aeronautics and Space Administration (NASA) played a crucial role. Both the transistor itself and the integrated circuit were first developed with private funds; but, in the latter case at least, military and space demand was certainly an important motivation, and once those innovations were clearly identified, government support of product and process engineering helped speed their advance. Similarly, the government funded much of the early research, and provided much of the early market, for the digital computer. Defense procurement and in recent years heavy government R & D funding have played a major role in the evolution of aircraft technology.

It is important to recognize that the efficacy of government procurement-related R & D depends on the knowledge-advantage that comes from the government's position as user and on the political legitimacy of its mission as justified on grounds other than spillover benefits. The conclusion thus does not extend to government procurement projects, the justification of which is the spillover itself or in which the procurement is intended to make a market for the technology. [The supersonic transport (SST) project remains the best case in point.]

Moreover, our case studies suggest that the potential for the generation of spillover by procurement-related government R & D support may be limited to the early stages of a technology's development, when government and civilian demands are not yet specialized. As a technology matures, the requirements of the government and the private sector normally diverge. This means not only that spillover diminishes but also that military and commercial R & D increasingly compete for resources. In the mature phases of a technology's development, spillover may be as much to the military from the commercial sector as the other way round.

Generic Technologies

When there is no recognized public-sector demand for a technology, the government's ability to fund R & D effectively and to guide the development of that technology is more limited. The government does not then have natural access to the sorts of information necessary to guide allocation, and may in fact be blocked from getting the information. Furthermore, the legitimizing effect of a public sector purpose is not there to protect a support program from strong political opposition.

Nonetheless, these problems may be attenuated if the government restricts its attentions to areas, such as so-called generic technology, that are a step or two removed from specific commercial application. The reason is that, at this "directed basic" level of research, the knowledge involved has a large public component: much of it is the sort of nonpatentable and nonspecific knowledge—broad design concepts, properties of materials, and testing concepts—that is generally shared among scientists and does not pose a strong threat to proprietary interests.

In a sense, such generic work falls in between the sorts of work that an academic researcher, pursuing fashionable questions within the bounds of a standard scientific field, would tackle and the kinds of result-oriented research that would interest most corporate R & D laboratories. Of course, some companies do support generic research, and the findings are very often treated as public rather than as proprietary. In many instances, the funding for such research comes at least in part from governmental sources. In either case, the keys to success seem to be, first, involving the relevant scientific and technical communities in the allocation process and, second, recognizing that research ought to be influenced both by the purely scientific disciplines and by those interested in applications; indeed, a tension between the pure and the applied is generally salutary.

Our case studies provide examples of generic research, some associated with government procurement (in aviation, computers, semiconductors) and some more commercially oriented work (certain aspects of agricultural and pharmaceutical science).

The agricultural sciences, viewed as a generic research system, seem to have defined and filled their niche appropriately. Such work fits in between the academic basic sciences (like chemistry and biology) and the applied R & D carried out in private firms and in the experiment stations (like the development of new seeds or fertilizers). Interests on both sides of the line pull and tug to influence the kinds of research that are done as well as to monitor its quality and efficacy. The biomedical research community is another example. Research here too is pulled by applied interests (the physicians) and tugged by scientists in the more basic fields. Interestingly, both the agricultural and the biomedical sciences typically reside in university settings, but in separate professional schools rather than main-line departments.

Another similarity between agricultural science and biomedical research is the way funding allocation is carried out. Both disciplines take the majority of their support from the government, but the funding agencies keep their distance, allowing the allocation machinery to be manipulated by the research communities themselves.

The National Advisory Committee on Aeronautics (NACA), the forerunner of NASA, is another example of a generic research system. Here the setting was a freestanding organization, not a university. But NACA's research concerns were certainly generic—broad-gauged aviation problems rather than specific designs—and the relevant engineering societies played a significant role in guiding and monitoring work at NACA. After World War II, the military increasingly assigned to private contractors the sort of work NACA had carried out, a trend that both reflected and abetted the divergence of military from civilian aircraft technology.

Because generic research poses a diffuse rather than a visible threat to established competitive positions, it may be possible to mount such a program successfully in any industry. But the size of the gray area between the basic and the applied may vary greatly among industries. Of course, the extent of this generic range may itself be influenced by the presence of a government program: the public financing of R & D often proves contagious, luring business scientists into a wider communications network and increasing the public flavor of private work. This is certainly desirable to the extent that it does not diminish the private incentive or ability to seize upon new ideas and develop them for market.

The manner in which a generic program develops may also be of critical importance. The aborted Cooperative Automotive Research Program (CARP) and the Cooperative Generic Technologies Program (COGENT) of the last administration seem to fit the description of generic systems, yet neither attracted the enthusiasm of the industries it proposed to aid, perhaps because the initiative and the design of the programs came strictly from Washington, with little participation by industry.

Clientele-Oriented Applied R & D

The most important characteristic of government support for basic and generic research is that it does not require government administrators to make decisions that involve considerations of profitability and commercial potential. A basic or generic research program seeks to advance scientific and technical knowledge, and the decisions involved require primarily scientific and technical knowledge. While acquiring this sort of knowledge is not a trivial matter, it can at least conceivably be marshaled by program administrators, especially since the relevant scientific community can often be enlisted to help guide allocation. Moreover, basic and generic research, which involves exploring widely applicable technological options, seldom poses a concentrated threat to proprietary interests.

When we move closer to the level of applied research, however, the problems of government involvement multiply. The knowledge involved is both specific and idiosyncratic in form and may be proprietary in character. This instantly puts the government administrator at an informational disadvantage vis-à-vis firms that have no incentive, and sometimes no ability, to transmit what they know to Washington. Moreover, it is difficult to maintain a political constituency for a program that poses visible threats to established competitive positions.

Now, there is one much-discussed example of a strikingly successful government program of applied R & D: the agricultural research system. As noted above, much of the research supported in this program has been basic and generic, but a sizable proportion has been extremely applied in character, focusing on particular objectives like better seed varieties or more effective pest control. The interesting question is: what special conditions have made this applied R & D program feasible and productive?

A crucial feature of the agricultural industry is that it is largely atomistic in form. The competition among farms is something near to the "perfect competition" described in economics textbooks rather than the more rivalrous kind that characterizes most manufacturing industries. For this reason, fellow competitors are seen as inherently less threatening in farming than in most other industries; technological knowledge is therefore far less proprietary, and there is a public cast to the results of even very applied R & D.

The federal-state system of agricultural experiment stations evolved in a way that took advantage of the market structure in agriculture, marshaling the support of the farmers and giving them an important position in the evaluation and selection of projects. Coupled with the regional nature of agricultural technology, this led to a system in which farmers see it as advantageous to them to advance even very specific technologies as quickly as possible. As a model for the administration of a government-supported applied R & D program, the agricultural system is quite instructive. It is highly decentralized, and specific resource allocation decisions are made at state and county levels. Those decisions respond with some sensitivity to the demands of two constituencies: farmers (given voice through state legislatures) and the agricultural science community.

In the language of the social scientist, we might call this a "captured" system, in much the same sense that transportation, communication, and other industries are said to have captured their regulators. Capture of this sort is not very often congruent with the general interest of consumers; but in the case of agriculture the system seems to have evolved in a salutary fashion.

The residential construction industry is also relatively atomistic in structure, and has therefore long been seen as conformable to the agricultural model. Yet several government efforts to spur housing R & D have not worked; more accurately, the housing industry beat back or cut back the government attempts to mount such programs.

There are probably many reasons for the nontransferability of the agricultural model to housing. Building is somewhat more rivalrous in character than farming, at least at the level of materials suppliers. More important, the atomistic home builder is very likely more conscious of a threat from housing innovation than is (or was) his atomistic counterpart in farming. Although agricultural innovation did in the long run lead to the demise of the small farmer by increasing the scale of farming operations, each small farmer could nonetheless see the benefit to him (in the short and medium run, at least) of improved farming methods. The builder may well be more aware that any exploitation of scale economies brought about by innovation would very likely redound to his disadvantage, posing a clear threat to the system of small local firms in which he operates. Another factor is that building codes—a very old form of "new social regulation"—are intractable and entrenched. And there is not the background of good basic science in housing that there is in agriculture.

Beyond that, however, it may have been crucial that the agricultural research system evolved slowly over time and was not constructed de novo or centrally designed. It may even be that its success derives critically from the particular path the system's development followed (for example, its growth out of what was essentially a training program for farmers) and particular historical circumstances (such as the characteristics of the 19th-century industry) that are not easily replicated.

Picking Winners

Which brings us to the final approach to government R & D support—"picking winners" in commercial competition. Here the historical record seems, for a change, unequivocal. Unequivocally negative.

The SST project and Operation Breakthrough were two examples touched upon in our case studies. In both cases, the government did not attempt to create a framework in which scientific and user interests could guide allocation; rather, the federal agencies attempted to insert themselves directly into the business of developing particular technologies for a commercial market in which they had little or no procurement interest.

In the case of Operation Breakthrough, the Department of Housing and Urban Development had been neither a major builder nor a buyer of nonsubsidized housing. It had neither the technical expertise nor the market experience that commercial success demands. Similarly, the government was not in the business of making or buying commercial airplanes; those who were, the commercial aircraft companies, showed little interest in such a plane until the prospects for high subsidies appeared. Very few of the housing designs that came out of Operation Breakthrough have since had any commercial value; and the lesson from the British-French Concorde experience is that we are lucky we went no further than we did with plans for an American SST.

The lesson here is not specific to these cases; it is not that these particular government agencies lacked some necessary expertise that could in principle have been remedied by hiring a larger or better cadre of experts. The lesson is a general one, about the location of knowledge and the mechanism of its transmission in the R & D system.

European experience testifies to the generality of the lesson (*10*). In many cases, government attempts to enter the business of commercial applied R & D led to (i) duplicating private efforts or (ii) subsidizing those efforts and thereby replacing private with public funds or (iii) investing in designs the private sector had long abandoned as unpromising. There is certainly an argument that the government can be more forward looking than a private firm, supporting projects that are unpromising today but may be promising tomorrow. But the most effective way to perform such a next-generation function is not by competing in the commercial marketplace but through research of a more generic sort.

Lessons for Policy

The conclusions of a comparative historical analysis can only be qualitative and judgmental. But perhaps the lesson of economic theory and political practice during the last couple of decades is precisely the importance of this sort of empirical analysis.

Our central conclusion might be summed up in one word: complexity. The wide diversity of technological and institutional details, of knowledge structures and incentive structures, among American industries recommends against an industrial policy to boost "industrial innovation" in some global sense in the hope of affecting macroeconomic problems. Broad-brush measures like tax policy, antitrust policy, and patent policy, which affect each of the various industries in a very different way, should be assessed on their own merits and should not be viewed as "control variables" to stimulate innovation.

We do not propose a general rationale or justification for active government support of R & D. Applying the lessons of history to create programs that are both politically viable and socially desirable is no straightforward task. But the historical experience we have examined reveals three approaches that have worked in the past: support associated with government procurement or some other well-defined public sector objective; support of defined nonproprietary research, with allocation funds guided by the appropriate scientific community; and provision of an institutional structure that allows potential users to guide the allocation of applied R & D funds.

A fourth kind of policy, whereby government officials themselves try to identify projects that will be winners in a commercial market competition, is always seductive, but the evidence, from our studies and others, suggests that such strategy is to be avoided.

References and Notes

1. R. R. Nelson, Ed., *Government and Technical Change: A Cross-Industry Analysis* (Pergamon, New York, 1982). The authors responsible for the industry studies are: agriculture, Robert Evenson, Yale University; automobiles, Lawrence J. White, New York University; commercial aviation, David Mowery and Nathan Rosenberg, Stanford University; computers, Barbara Katz, New York University, and Almarin Phillips, University of Pennsylvania; housing, John Quigley, University of California, Berkeley; pharmaceuticals, Henry Grabowski and John Vernon, Duke University; and semiconductors, Richard Levin, Yale University. The study was supported by grant NSG7636 from the National Aeronautics and Space Administration.
2. Each author (or pair of authors) was responsible for an individual chapter, but the group agreed on a common format for the cases, and it met several times (sometimes with other scholars and representatives from government and industry) to discuss and integrate the chapters. R. Nelson was responsible for a synthetic "cross-cutting" chapter, which was in turn discussed and commented upon by the group.
3. The most influential of these models was by Kenneth Arrow [K. Arrow, "The allocation of resources to invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, R. R. Nelson, Ed. (Princeton Univ. Press, Princeton, N.J., 1962)]. But see also H. Demsetz, "Information and efficiency: Another view," *J. Law Econ.* **12**, 1 (1969).
4. K. Arrow and R. Lind, "Uncertainty and the evaluation of public investment," *Am. Econ. Rev.* **60** (No. 3), 364 (1970).
5. The notion that "competitive"—that is, atomistic—firms innovate less than larger, "oligopolistic" firms has been called the Schumpeterian hypothesis, since those who read the work of Joseph Schumpeter through a certain set of spectacles discerned an argument of this sort in his *Capitalism, Socialism, and Democracy* (Harper, New York, 1942). The argument was stripped down to a more elemental form and popularized by John Kenneth Galbraith, especially in his *The New Industrial State* (Houghton-Mifflin, Boston, 1967).
6. Organization for Economic Cooperation and Development, *Technical Change and Economic Progress* (Organization for Economic Cooperation and Development, Paris, 1980). It may be significant that both the United States and Britain devoted an unusually high fraction of R & D to defense. But even when differences in defense R & D spending are accounted for, intercountry differentials in productivity growth seem better correlated with such matters as physical investment than with overall R & D spending.
7. N. Rosenberg, "U.S. technological leadership and foreign competition: 'De te fabula narratur?' " (photocopy, Stanford University, November 1981).
8. R. R. Nelson and S. Winter, "In search of a useful theory of innovation," *Res. Policy* **6**, 36 (1977).
9. R. R. Nelson, "Research on productivity growth and productivity differences: Dead ends and new departures," *J. Econ. Lit.* **19**, 1029 (1981).
10. See generally K. Pavitt and W. Walker, "Government policies toward industrial innovation: A review," *Res. Policy* **5** (No. 1) (1976).

Mr. **Mares.** In the past when the Government did assert itself as a decision-maker in these stages, it sometimes made the correct choice. It picked the right technical concept to pursue. However, I am convinced there have been many times when Government's involvement in the process development and commercialization stages of R&D has disadvantages. For example, privately financed competing concepts, some of which might ultimately have had better potential, are overlooked.

Especially in these times of budget deficits, a Federal dollar spent in these latter stages of R&D has a double impact. It not only takes a dollar out of the private capital funds, but it may also preclude a dollar from being spent by a commercial firm developing a competing process.

Therefore, the budget we have put together emphasizes generic research and development, that is, R&D which may have a substantial payoff but the benefits of which at the present stage of research are not specific to an individual company. The major part of our budget request is concentrated on basic and applied research, particularly applied, where there are inherent limitations on a private company's ability to capture the rewards of this type of research.

On page 3 of my prepared statement, I have indicated the relative priorities that were used to determine our funding levels within fossil energy. As with last year, our strategy gives highest priority to establishing the technical data bases that will enable industry to develop new sources of liquid fuels and substitutes for petroleum. This priority includes our enhanced oil recovery program, our oil shale and tar sands activity, coal liquefaction, and those aspects of gasification which are critical to liquefaction and technologies that will enable coal to be substituted for oil in utility and industrial applications.

Together the program elements that make up this priority account for more than 60 percent of our $138 million budget request we are making.

We are making progress in the transfer of our three western Energy Technology Centers to non-Federal entities. On February 28, the Department and the University of North Dakota signed an agreement transferring the Grand Forks Energy Technology Center to the university effective April 1. This past Saturday, we completed a similar action with the University of Wyoming involving the transfer of our Laramie Energy Technology Center.

In the case of the Bartlesville Center, we have begun evaluating proposals received by the closing date last Friday. These are proposals for the operation of that facility with the Federal Government continuing to own the facility.

In all of these cases I would like to reemphasize my continued belief that the transfer of these centers will lead to a significant expansion of their usefulness to the country. They have more to offer than we have the capability to support. In the near future, permitting them to expand their productivity beyond that which can be funded only by the Department of Energy will not only in my judgment be in their best interest, but in the interests of the country as a whole.

The final point I would like to make, Mr. Chairman, is more a matter of bookkeeping. In the 1983 budget, Congress directed the Department to separate the management and administrative costs for the technology centers, the so-called indirect costs from the direct program costs. We were too far into the budget formatting process for fiscal year 1983 when the direction was given to identify these costs as a separate line item. Consequently, we have recently provided this committee a breakdown of the estimated $33 million ETC program direction costs that are part of the $138 million overall request.

Mr. Chairman, in summary we believe this budget is responsive to the twin challenges before us—first, to continue the necessary restraints on Federal spending while second, to establish a sound base of technological understanding that will be needed by future generations.

We believe Government can play a useful role that will complement rather than compete with the private sector, and we believe this budget proposal represents a realistic approach toward fostering the type of consensus that will permit a sustained core level of effective fossil energy R&D to continue.

Thank you, Mr. Chairman. I would be happy to respond to your questions.

[The prepared statement of Mr. Mares follows:]

STATEMENT OF JAN W. MARES
ASSISTANT SECRETARY FOR FOSSIL ENERGY
U.S. DEPARTMENT OF ENERGY
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT
SENATE COMMITTEE ON ENERGY & NATURAL RESOURCES
MARCH 21, 1983

Mr. Chairman and Members of the Committee:

The Fiscal Year 1984 Fossil Energy budget request continues the transition begun in 1982 from a technology program that emphasized large, process-specific pilot and demonstration facilities to one that is now concentrated on more generic basic and applied research.

The Nation is fortunate to have abundant fossil energy resources. Our deposits of coal, petroleum, oil shale, tar sands, and natural gas exceed the known fossil energy resources of any other nation. Still, diverse and extensive advances are needed in our scientific and engineering knowledge base to use these resources effectively. Much of the needed process development and commercialization of new technologies will come from the industrial sector in response to market incentives. To support these private initiatives, we continue to view the creation of a fundamentally sound knowledge base as an appropriate and important role for the Federal Government.

The FY 1984 budget request of $138 million for Fossil Energy research and development represents the Administration's effort to fashion a sound, core program that will continue to produce the technological information the Nation will need in order to develop and deploy advanced energy options. Still, it is a request that has been developed within the framework of the serious budget deficit problems that confront us as a Nation.

The Economic Context of the FY 1984 Budget Request

The energy-related R&D portions of the Department of Energy budget, and thus the Fossil Energy component, are part of the Federal government's non-defense discretionary programs. The President has emphasized the need for a freeze on the aggregate of these programs in FY 1984 relative to the 1983 appropriations. This is an integral part of the goal to reduce the structural deficit, and it is reflected in the overall Administration budget proposals. Within the aggregate of non-defense discretionary programs, however, there are obviously some increases and decreases.

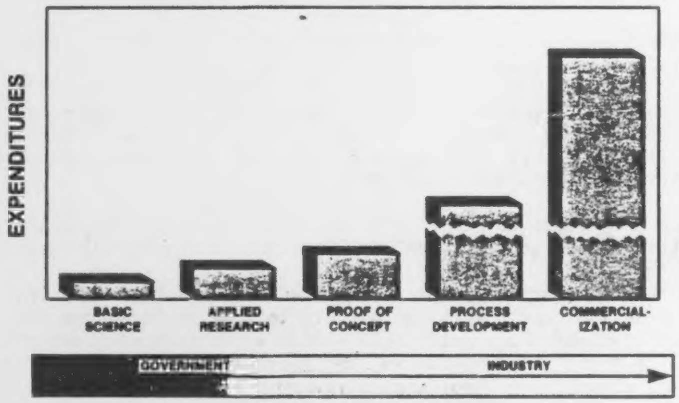
In developing the FY 1984 budget, the Administration, the Department of Energy, and the Office of Fossil Energy have evaluated many requests and potential uses for government funds that are neither possible nor appropriate within the context of the President's economic and energy programs. In selecting the research projects included in our budget, we have focused on those elements that attract little or no private funding. The risks, costs, or payoffs are either too long-range or uncertain, or the benefits are not specific to the private funder.

The FY 1984 budget request for Fossil Energy R&D represents a 29 percent increase over the Administration's request in FY 1983. While this is admittedly much less than the $311 million appropriated in FY 1983, it reflects an effort to work with the Congress in developing the most appropriate mix of programs. We have made some very hard decisions in order to achieve our overriding goal of reducing the deficit and improving the economy. Nonetheless, within the context of a very fiscally constrained year, we believe we are presenting to the Nation a rational, balanced and adequate Federal budget for Fossil Energy research.

The FY 1984 Fossil Energy Strategy and Priorities

If the U.S. is to continue to maintain its technological leadership in energy, systematic advances must occur in all stages of the research, development and commercialization cycle -- from basic science to applied research, proof-of-concept, process development, and finally to commercialization. These steps are shown graphically in the following chart:

TECHNOLOGY DEVELOPMENT PATH



The latter stages of this development path are the most costly, and this is where extensive private sector investments have occurred in the past and will continue to be required in the future.

The earlier stages, through proof-of-concept, feed the private sector R&D investment pipeline. While the projects in these earlier stages may have a very high benefit/cost ratio from a national perspective, private sector investment is often limited or nonexistent. The ultimate benefits of these early stages of research may be quite large, yet they are frequently difficult to predict, highly risky, or long-term, or cannot be captured by private firms. Thus, there is a valid Federal role to provide front-end R&D support in a diversified spectrum of fossil fuel technologies.

The Department of Energy's FY 1984 budget, therefore, is oriented principally toward the applied research portion of the technology development path, with some effort also in the basic science and the "proof-of-concept" stages. Because the Federal role is focused on these more generic aspects of R&D, private industry is thus able to select those technologies warranting scale-up with its own funds without governmental bias or interference.

Fossil Energy Priorities

Recognizing the prospects of a continued domestic reliance on liquid fuels, the Fossil Energy strategy gives high priority to establishing data bases that will enable industry to develop new sources of liquid fuel supplies and petroleum substitutes with acceptable environmental impacts. This priority includes:

- advanced technologies for recovering oil from large, currently unrecoverable petroleum resources;
- advanced concepts for producing oil from shale and tar sands, and from coal via direct and indirect liquefaction;
- those aspects of coal gasification which are critical to advanced liquefaction processes;
- advanced technologies (including aspects of combustion, control technology, heat engines, and fuel cells) that substitute coal for oil in utility and industrial applications where conventional coal-fired technology is now precluded.

More than 60 percent of the $138 million requested for Fossil Energy R&D relates specifically to the "liquids" and "liquids displacement" priorities.

The Fossil Energy strategy recognizes several other high priority areas. Gaseous fuels can substitute for liquid fuels in many applications. Unconventional gas resources can provide this Nation an abundance of new gaseous fuel supplies if today's scientific and engineering knowledge can be expanded for associated extraction technologies.

Another high priority deals with establishing the scientific and engineering foundations for the use of coal and other abundant fossil energy resources through improved technologies. Inherent in the technologies being pursued in this priority is the potential for large payoffs in improved economic and environmental performance, increased efficiency, and greater flexibility of coal use. This priority includes aspects of control technology, combustion systems, and fuel cells. Also within the Fossil Energy priorities are generic and crosscutting research that can contribute to economically efficient energy production in the future.

All of the R&D conducted within the Fossil Energy program is coupled with appropriate environmental research. Specifically, we are working to establish data bases that will help industry mitigate and resolve problems rather than merely expand the range of questions and concerns. Potential impacts are characterized within our program, and the performance of new and developmental systems for controlling these impacts are evaluated. In this way, cost beneficial solutions to environmental concerns will be available on a schedule consistent with the progress of technology development.

The FY 1984 Fossil Energy Budget Request

The FY 1984 Fossil Energy budget request is made up of three major components:

	FY 1984 Budget Authority
Coal	$ 109.45 million
Petroleum	23.35 million
Gas	5.20 million
Total	$ 138.00 million

Within the $138 million request, the Administration is requesting $94 million of new budget authority. The remaining $44 million is available from prior year budgets, as shown below, and would be applied to the 1984 program.

Appropriation Transfer from Alternate Fuels Production Program (P.L. 96-126)	$ 13 million
Prior Year Offset	$ 31 million

The $13 million is derived from unexpended funds from the Alternative Fuel feasibility studies and cooperative agreements program authorized by Congress in 1979. A total of $31 million remains unobligated from Fossil Energy R&D budgets prior to FY 1983, including funds from the gasification demonstration plant projects (construction and operating expenses), the Solvent-Refined-Coal II demonstration project (construction and operating funds), the Pittsburgh Energy Technology Center Program Support building (construction funds), and the Program Direction (Headquarters) budget.

As the Committee is aware, P.L. 97-257 transferred the coal mining research and development program to the Bureau of Mines in the Department of Interior; therefore no funds are requested in the FY 1984 Fossil Energy R&D budget for Mining R&D.

The major budget categories of the FY 1984 request are described as follows:

COAL

COAL LIQUEFACTION

(Budget Authority In Millions)

FY 1982	FY 1983	FY 1984 Request
$ 98.8	$ 37.6	$ 17.0

The goal of the Coal Liquefaction program is to contribute to a data base that will facilitate the private sector's development of improved coal conversion processes. Products obtained from coal liquefaction can replace petroleum products as boiler fuel for utilities or can be refined to transportation fuel, furnace oils, and chemical feedstocks. Coal is, by far, the largest domestic fossil energy resource available to the U.S., and it is anticipated to be utilized eventually as a feedstock to increase the supply of liquid fuels.

An industry based on indirect liquefaction -- where coal is first gasified, then converted into liquid products -- could be initiated using commercially demonstrated process steps based, in large degree, on foreign technology. At the present state of development, however, indirect liquefaction processs are high cost and have relatively low thermal efficiencies. These processes could be improved if advanced, more efficient gasifiers, many of which are now becoming commercially available, are employed. These gasifiers, however, produce a syngas with a relatively low hydrogen content. Therefore, the DOE indirect liquefaction program is developing improved syngas conversion processes that are capable of functioning effectively using low-hydrogen content syngas.

Direct liquefaction promises lower costs and improved thermal efficiencies. The technical viability of a limited number of direct liquefaction processes has been demonstrated (Exxon Donor Solvent, H-Coal, Solvent-Refined-Coal) but commercial application has not yet occurred. New advances in catalysts and in the multi-stage direct liquefaction approach may improve the future commercial prospects of this technology.

FY 1984 Budget ($ in millions)

o Indirect Liquefaction ....$ 4.0

- — Complete funding of fluid bed methanol-to-gasoline project with the Federal Republic of Germany.
- — Continue bench scale research into new catalyst systems and process concepts.

(continues on next page)

- o Advanced Process Development ....$ 9.0 (direct liquefaction)
  - — Continue bench scale R&D in catalyst development and improved process concepts.
  - -- Continue bench scale R&D in integrated two-stage liquefaction (ITSL).
- o Support Studies/Engineering Evaluations ....$ 4.0
  - — Continue engineering evaluations and component research.
  - — Continue health effects and data base management activities.

SURFACE COAL GASIFICATION

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$54.2	$39.0	$16.9

By means of gasification, coal can be used for the economic production of gases having heating values that range from low/medium-Btu gas for industrial and electric utility uses to high-Btu gas of pipeline quality that can be used to supplement supplies of natural gas. Gasification technology can also be used to produce a synthesis gas suitable for subsequent conversion into a variety of liquid fuels or for use as a feedstock for the manufacture of chemicals. This flexibility in the conversion of coal into alternate forms of clean energy is being acquired through the development of advanced gasifiers and gasification processes that have the capability to utilize a wide range of U.S. coals having widely differing physical properties and chemical compositions that characterize these heterogeneous feedstocks.

In FY 1983, the major gasification process development units and pilot plant projects will be completed, including the BiGas concept for converting coal into a substitute natural gas and the agglomerating pressurized fluidized bed gasifier technology for the production of low and medium-Btu gas. Therefore, the proposed FY 1984 budget would continue to redirect the program from the development of specific gasifier concepts to the investigation of more generic gasification systems.

Emphasis will be placed on improving the understanding of the entrained and fluidized bed gasification concepts, using small units at the Morgantown Energy Technology Center and cold flow models. Work will also continue on increasing today's knowledge base for advanced carbonization-type reactors operating on a variety of coals over a broad range of operating conditions. Studies of the characteristic effluents from certain gasifiers will be conducted, and advanced cleanup components and systems as well as a novel dirty gas heat exchanger concept will be evaluated. Research will also be done to improve the materials and designs of critical components in coal gasification systems, such as heat exchangers, expanders, compressors, and valves.

The FY 1984 budget would also provide sufficient funds to continue monitoring the Great Plains coal gasification project in North Dakota, construction of which is nearly 40 percent complete and progressing toward a planned December 1984 target date for full gas production.

FY 1984 Budget ($ in millions)

o Advanced Process Development .... $ 4.0
  - Continue tests on small entrained-bed and fluidized-bed reactor systems to understand parameters that must be controlled to successfully operate advanced gasifiers.
  - Conduct basic experiments on advanced waste water treatment processes.

o Systems Engineering Concepts .... $ 6.9
  - Continue support of key gasifier data base studies essential to technology transfer and advancing state-of-the-art.
  - Continue efforts to resolve state-of-the-art instrument and equipment problems and to increase gasifier systems reliability.

o Environmental and Engineering Analyses .... $ 3.0
  - Continue only high priority projects having potential to provide solutions to problems identified as being technology limiting.
  - Continue efforts to determine the capabilities and limitations of cleanup systems and the environmental impact of zero waste discharge requirements.

o Great Plains Project .... $ 3.0
  - Continue project monitoring and management activities.

UNDERGROUND COAL GASIFICATION

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$8.3	$6.0	$2.0

Underground Coal Gasification (UCG) is an unconventional method to produce fuels by gasifying seams of coal "in situ" without mining. Underground coal gasification can convert solid coal underground to more easily recovered gaseous products that can either be directly utilized or converted to a suite of hydrocarbon products. Successful adoption of these processes could quadruple U.S. coal reserves while providing fuels at potentially lower costs and with less adverse environmental impacts than other synthetic fuels options. The expected final products using gas generated by this technology could be transportation fuels (primarily methanol and gasoline), electric power, industrial heating, synthetic natural gas, chemical feedstocks, and in site specific cases, CO_2 for enhanced oil recovery and hydrogen for refinery use or shale oil upgrading.

The FY 1984 budget would continue the development of a promising new concept in underground coal gasification, the Controlled Retracting Injection Point (CRIP) process. The basic concept of the CRIP system is to keep the burn zone growing in the upstream direction by cutting off or perforating the air or oxygen/steam injection pipe at successive new locations at the base of the coal. There is strong evidence that maintaining the injection point at a low position in the coal seam is essential for obtaining good gas quality and high resource recovery.

FY 1984 Budget ($ in millions)

o Environmental and Advanced Research .... $ 2.0
  - Continue post burn environmental research and monitoring.
  - Complete cost shared proof-of-concept test of Controlled Retracting Injection Point (CRIP) concept.

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$56.3	$36.0	$30.5

The Advanced Research and Technology Development (AR&TD) activity plays an important role in the Department's Fossil Energy program through development of the technology base in coal. Basic, applied, and exploratory high risk, potentially high payoff research at the Energy Technology Centers and National Laboratories, universities and industrial laboratories helps extend the fundamental scientific and engineering knowledge base providing ideas for new processes and technical breakthroughs in coal conversion and utilization.

FY 1984 Budget ($ in Millions)

o Direct Utilization .... $ 4.8
  - Continue coal combustion research.
  - Continue generic research in coal cleaning and control technology.
  - Continue research related to improving combustion processes for fluidized-bed technology.

o Materials and Components .... $ 6.5
  - Continue research in the areas of high temperature corrosion, slag refractory interactions, structural ceramics, hydrogen effects, and erosion wear.
  - Continue research into novel heat exchanger concepts.
  - Continue research on novel, advanced "dirty gas" valve concepts such as power fluidics, and multiple orifices.
  - Continue efforts on slurry pumps and critical subsystems such as check valves, seals, and materials for stuffing boxes.

(continued on next page)

o Processes $7.0
  - Continue research, principally at ETC's, on low rank coal liquefaction, development of analytical techniques and reaction chemistry.
  - Conduct research on advanced liquefaction concepts.
  - Continue research on catalysis and kinetics, structure and reactivity of coal, properties of coal, properties of coal liquids, and liquefaction of synthesis gas.
  - Continue research on coal conversion fundamentals to generate data needed to advance the state-of-the-art of gasification to the next generation of development.
  - Continue research along a broad technical front involving kinetics, thermodynamics, catalytic mechanisms, modeling, hydrogasification, pyrolysis, fluidization studies, acid gas removal, hot gas cleanup, gas separation, conversion studies and novel concepts of gas generation by reaction of coal with steam, air and oxygen.
  - Continue basic studies on the relationships of coal and components and coal behavior during gasification.

o Program Development and Coordination .... $ 1.7
  - Perform crosscutting support for policy development, R&D assessment and environmental, safety and health compliance overview for Fossil Energy. ($1.0)
  - Continue overall planning and policy development for Fossil Energy. ($0.7)

o University Coal Research .... $ 4.0
  - Initiate or renew approximately 25 university projects directed at improving the fundamental scientific and technical understanding of the chemical and physical processes involved in the conversion and utilization of coal.

o Construction .... $ 5.0
  - General Plant projects. ($2.0)
  - Wastewater treatment facility, METC. ($2.0)
  - Surface water containment facility, PETC. ($1.0)

o Capital Equipment .... $ 1.5
  - Provides for necessary capital equipment at ETC's and National Laboratories.

CONTROL TECHNOLOGY AND COAL PREPARATION

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984
$ 25.2	$ 27.9	$ 17.1

The purpose of the Control Technology and Coal Preparation program is to help private industry develop advanced technologies necessary to maximize environmental quality and minimize the cost of energy used by coal-fired utilities and industry. Current efforts concentrate on coal preparation, flue gas cleanup, and gas stream cleanup.

The current program is an outgrowth of research begun in FY 1979 to develop new, advanced concepts for environmental control technology, specifically in flue gas and gas stream cleaning. In FY 1983, the coal preparation R&D work was transferred from the mining program. This permitted a comprehensive program to be developed in Control Technology Systems that includes all aspects of cleanup R&D, from precombustion (coal preparation) to in-process (gas stream cleanup) through post-combustion (flue gas cleaning and waste management).

The objective of the coal preparation activity is to develop technologies which can remove sufficient quantities of ash and sulfur from coal so that coal can be substituted for oil and natural gas in many applications. In FY 1983, laboratory research will be completed on two advanced concepts -- fused salt desulfurization and microwave processing. Both have the potential for reducing the sulfur and ash in coal to levels comparable to fuel oil. Laboratory evaluations of the high gradient magnetic separation process will also be completed. This technique is effective in removing inorganic sulfur (occuring as pyrite) and ash from finely-ground coal. Testing of the two-stage froth flotation technology to extract minerals and pyrites from coal will also be concluded in FY 1983.

With these activities concluding in FY 1983, the FY 1984 coal preparation program will focus on evaluating the critical engineering design and performance issues in the areas of: physical cleaning of fine coal; comminution (size reduction) and fine coal dewatering and consolidation; chemical cleaning; and dewatering and beneficiation of low rank coals and lignites.

Flue gas cleanup activities were significantly reoriented in FY 1983 to concentrate on technologies that remove nitrogen oxides (NO_x), sulfur oxides (SO_x), and in some cases, particulates, simultaneously rather than in multiple cleanup steps. A "proof-of-concept" unit for the E-beam (electron beam)/lime flue gas cleanup concept will be completed in FY 1983, and testing will begin. Construction of a "proof of concept" unit for a similar concept, which would substitute ammonia for the lime in an E-Beam system, will begin in FY 1983, with testing scheduled for 1984. Studies were begun in FY 1983 on several innovative concepts for simultaneous NO_x/SO_x removal systems, and in FY 1984, one of these concepts will be evaluated at bench scale.

In the gas stream cleanup program, proof-of-concept testing will be completed in FY 1983 on an electrostatic precipitator specially designed for controlling particulates from a pressurized fluidized bed combustor, and bench scale evaluations will begin of selected advanced particulate control systems. Evaluations of a zinc ferrite desulfurization process capable of operating in the temperature range of a fluid-bed coal gasifier will be conducted in FY 1983, and in FY 1984, the process will be linked with a gasifier for testing.

Funding for sampling and characterizing coal derived wastes will be completed in FY 1983, with some contractual efforts concluding in FY 1984. Using the information from previous activities, a waste characterization data base and Resource Conservation and Recovery Act impact assessment will be compiled in FY 1984.

FY 1984 BUDGET (BA in millions)

- Coal Preparation..$ 5.0
  - Define basic technological design and operating requirements for cleaning U.S. coals to quality levels comparable with oil.
  - Evaluate critical engineering design and performance issues in fine coal cleaning and conditioning, chemical cleaning, and low rank coal beneficiation.

- Flue Gas Cleanup..$ 7.6
  - Complete testing of the electron beam/ammonia PDU
  - Continue the development of combined NO_x/SO_x flue gas cleanup concepts.
  - Initiate systems integration studies to combine $NO_x/SO_x/$ particulate capture in one process.

- Gas Stream Cleanup..$ 4.5
  - Continue lab scale R&D effort on particulate and alkali removal concepts.
  - Complete preliminary economic/performance analysis for selected pressurized fluidized bed combustion cleanup devices.
  - Test the zinc ferrite desulfurization process on one gasifier.

HEAT ENGINES

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$15.4	$ 5.0	$ 1.0

The Heat Engines program is directed toward establishing a firm technology base which could enable the private sector to assess technical data and ultimately, the commercial viability of coal-fired power conversion systems. Current efforts are focused on high risk research on the use of coal-liquid slurry mixtures and coal-derived gaseous fuels in such heat engines as gas turbines and diesel engines.

FY 1984 Budget ($ in millions)

- Heat Engines .... $ 1.0

  - The technology base efforts initiated in FY 1982-1983 period will be completed and a final report including detailed analyses of the data will be prepared and distributed to interested Federal agencies and private sector concerns.

COMBUSTION SYSTEMS

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$30.5	$24.2	$ 8.4

The objective of the Combustion Systems activity is to conduct generic technology base development with potential for high payoff related to advanced coal and coal-derived fuel combustion concepts. These research efforts are intended to establish the technology base from which industry can develop, demonstrate and commercialize improved systems which can allow for the expanded utilization of coal in an environmentally acceptable manner; particularly, as a replacement for oil and/or natural gas in utility, industrial, residential/commercial and transportation applications. The programs involve generic research on atmospheric and pressurized fluidized bed combustion and alternate fuel mixtures.

In FY 1983, work was completed in the operational phase of the atmospheric fluidized bed (AFB) industrial-scale projects at Georgetown University in Washington, D.C., at Shamokin, Penn., and at the Great Lakes Naval Training Center near Chicago. Construction was begun on two AFB boilers, in East Stroudsburg and Wilkes-Barre, Penn. Also, the initial evaluation of seven advanced atmospheric fluidized bed concepts was completed. The final Federal funding shares for the construction of the pressurized fluidized bed pilot plant at Wood-Ridge, New Jersey, and the operation of the IEA project in Grimethorpe, England, were provided. Operation continued at the New York University, Long Term Materials, and CURL PFB test facilities. Testing also continued to characterize coal-water slurry and other coal-liquids mixture technologies.

FY 1984 BUDGET ($ in Millions)

o Atmospheric Fluidized Bed Combustion	$ 1.0
- Conduct bench-scale testing of the most promising of the previously identified advanced AFB concepts.	
o Pressurized Fluidized Bed Combustion	$ 3.4
- Evaluate a wide range of alternate coal feedstocks, i.e., coal-water, lignite, large (run-of-mine) coal. - Continue the long-term materials program.	
o Alternative Fuel Utilization	$ 4.0
- Continue coal-water mixtures characterization efforts initiated in FY 1982. - Continue efforts in other coal-liquid mixtures technology areas (peat-coal-ethanol/methanol, etc.) to expand potential application into new-use areas. Specific attention to fuel particle size and distribution phenomena.	

FUEL CELLS

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$34.5	$30.1	$ 9.5

The objective of the Fuel Cell activity is to establish technical feasibility of fuel cell power plants for electric utility applications, industrial cogeneration, and for on-site total energy systems. The fuel cell system is a revolutionary hydrocarbon fuel conversion technology to increase the cost effective, efficient and environmentally acceptable use of conventional and alternative hydrocarbon fuels, thereby reducing demand for oil.

The Fuel Cell program is developing technology for phosphoric acid, molten carbonate and solid oxide fuel cells. The program is part of an overall mission-oriented effort in which the private sector is responsible for demonstration and commercialization activities, the bulk of the engineering activities and part of the technology base development, with the government funding some generic technology base development of the cell and stack technology components.

Research in the area of thermionics will be completed in FY 1983.

FY 1984 BUDGET ($ in Millions)

o Advanced Concepts	$ 1.5
- Research efforts on solid oxide fuel cells will be focused on continuing selected technology base efforts, including the completion of the first integrated system design.	
o Molten Carbonate Systems Development	$ 5.0
- Fabrication and test of full area cells. - Test cells with advanced integrated components. - Complete 10,000 hour test of commercial cell type	
o Phosphoric Acid Systems Development	$ 3.0
- Continue electric utility R&D subscale stack tests.	

MAGNETOHYDRODYNAMICS

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$21.8	$29.0	$ 0

The Department began significant Magnetohydrodynamics (MHD) development programs in 1974. MHD is a long-range energy conversion technology with the potential of converting coal to electricity with high overall efficiency (in the 48-55 percent range, in mature systems, compared to about 35 percent for conventional coal fired systems), low cost of electricity, and low environmental intrusion with direct coal firing.

The FY 1983 program focused on the continued development of coal-fired MHD technology with emphasis on power train testing at the Component Development and Integration Facility (CDIF), at Butte, Montana, and the Heat Recovery Seed Recovery (HRSR) trains at the Coal Fired Flow Facility (CFFF), at Tullahoma, Tennessee. The objective has been to establish the critical technology base for subsequent industrial commercialization of MHD systems by the private sector.

The Department proposes to phase out the MHD program beginning in FY 1983 and to close out facilities and bring other ongoing efforts to an orderly conclusion. Although MHD is one of several advanced fossil energy technologies that could potentially increase power plant efficiencies and improve the environmental performance of coal-fired power plants, it has high risks and much higher costs relative to other advanced electricity generating technologies under development. The MHD program will entail future development costs as high as $250 million for continued technology base research and up to $300 million for a multimegawatt proof-of-concept facility while offering potential benefits similar to these other coal-based options. In light of this, no funds have been requested in FY 1984 for continuing the development of MHD technology.

The Department will notify Congress prior to initiating these proposed close-out activities.

PETROLEUM

ENHANCED OIL RECOVERY

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$16.2	$ 6.5	$11.25

The goal of the Enhanced Oil Recovery (EOR) program is to conduct generic technology base R&D activities and to assist industry in obtaining a better understanding of the mechanisms and behavior of advanced and novel EOR processes for heavy oil, light oil, and tar sands.

In FY 1983, the final report was completed on the long-term test of the downhole steam generator, a concept now being developed for commercial application by several private firms. In a related area, evaluations of a concept for insulating the well string to permit deeper injection of steam for heavy oil recovery were completed. Monitoring of the on-going cost-shared and Economic Regulatory Administration incentive test projects continued, as did several university research programs attempting to improve the basic understanding of light and heavy oil recovery processes. Several field experiments of steam with foam and one involving miscible gas flooding were completed. An in-depth analysis and tabulation of candidate U.S. reservoirs for miscible gas and chemical flooding was also completed and made available for public use.

The FY 1984 budget request of $11.25 million for enhanced oil recovery represents an increase over the $6.5 million appropriated by the Congress in FY 1983. The increase would be principally applied to expanding fundamental research in flow properties, combustion kinetics, steam mobility control, steam additives and thermal mapping for heavy oil recovery, and increasing the research program in rock/fluid interactions, mobility control, chemical stability, predictive models, data base development and technology transfer for light oil recovery. A smaller increase would also be used to increase experimental work for in-situ recovery of oil from tar sands using a block test apparatus and for defining process parameters for steam flooding and in-situ combustion in tar sand reservoirs.

FY 1984 Budget ($ in millions)

o Heavy Oil .... $ 3.7

  - Initiate studies on the effect of noncondensable gases with steam relative to improved oil recovery.
  - Perform post-flood analyses of City of Long Beach and Aminoil's caustic floods.
  - Begin experiments on unconsolidated formations to verify theory and model for horizontal holes (heavy oil mining R&D).
  - Analyze results of controlled source and high frequency electromagnetic tracking results for an in situ combustion and/or steam recovery project.
  - Complete the mathematical model for fuel deposition and related parameters of the in situ combustion process.
  - Complete studies on the effect of pressure temperature on reservoir parameters.
  - Complete survey and analysis of potential techniques for determining steam quality and initiate development of test equipment of selected techniques.
  - Begin combustion tube tests to determine effects of using oxygen injection as an alternative to air on the kinetics of the in situ combustion process and model the results.
  - Continue international research activities.

o Light Oil .... $ 6.6
  - Continue chemical and miscible gas flooding R&D consisting of fundamental research on displacement mechanisms and advanced recovery processes; EOR data base analysis related to FE and ERA-incentive tests.
  - Expand research on rock-fluid interactions in chemical flooding; miscible gas plus additives development; EOR data base extension and post-test analyses.

o Tar Sands .... $ 1.0
  - Continue R&D efforts into displacement mechanisms, forward and reverse in situ combustion methods, hot fluid injection such as cyclic steaming and steam flooding, tar sand mining, recovery through underground mining and drilling techniques, environmental research for both air and water quality, and alternate extraction technologies.
  - Continue technology exchange agreements with Venezuela and Canada.

ADVANCED PROCESS TECHNOLOGY

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$4.0	$5.0	$2.9

The goal of the Advanced Process Technology (APT) program is to pursue the identification and development of advanced extraction, processing, and utilization concepts and technology related to oil, gas, tar sands, shale oil and unconventional hydrocarbons.

Within this program are efforts to assist industry in developing novel and innovative technology, such as microbial enhanced oil recovery, to increase the efficiency of extracting usable fuels from oil, gas and shale resources. New, improved analytical methodolgy and the instruments necessary to determine the chemical and physical properties and the composition of liquid fossil fuels are also expected to emerge from the generic research conducted under this budget item. Also included is the fundamental research necessary to identify, isolate, and remove toxic products from heavy crude, shale oil, and tar sand bitumen.

In FY 1983, a new initiative was undertaken in this program dealing with high-risk research related to Arctic and offshore environments. Specific activities were begun to study such areas as seafloor engineering and sea-ice dynamics.

Within this activity is also the coordination and planning of advanced petroleum- and gas-related research, including the Office of Fossil Energy's involvement in international activities.

FY 1984 Budget ($ in Millions)

- o Advanced Exploratory Research .... $ 2.2
  - Continue basic research into separation techniques development, crude oil analyses, instrumentation and technique development, and storage/handling fuel stability studies regarding petroleum products and resources.
  - Perform basic characterization research on Cerro Negro heavy crudes under a cooperative agreement with Venezuela.

- o Arctic and Offshore Research .... $ 0.7
  - Continue monitoring and coordinating role for energy-related Government Arctic research activities.
  - Standardize the collection, correlation and analysis of data to establish a uniform data base of Arctic and offshore information.

OIL SHALE

(Budget Authority in Millions)		
FY 1982	FY 1983	FY 1984 Request
$19.2	$12.3	$ 8.6

The Oil Shale program is designed to develop a sound technology base in oil shale chemistry and engineering which will assist industry in the development of oil shale technology.

The U.S. oil shale resource is estimated to be about two trillion barrels of oil equivalent with the richest deposits found in the states of Colorado, Utah, and Wyoming. Substantial lower quality resources also occur in the East. Oil shale technology is now in the process of moving from the laboratory and pilot plant stage to the first commercial attempts. The first plants can comply with current environmental standards using available technology; however, over a period of time, it may be necessary to mitigate environmental pollution because of regional impacts. Water quality may also prove to be a constraint on the expansion of a western oil shale industry.

In view of these potential limitations on the future contribution of oil shale to the Nation's energy mix, the Federal program was reoriented in FY 1982 and FY 1983 away from major project activities and toward the completion of data analysis and generic research from which a new generation of more efficient and environmentally acceptable oil shale processes might emerge. The FY 1984 program would continue, although at a reduced scope, basic research begun in FY 1983 on the chemistry and physics of oil shale processes and the study of the environmental implications of various oil shale conversion mechanisms.

FY 1984 Budget (BA in millions)

- o Oil Shale Technology Base .... $ 4.3
  - Continue laboratory research on chemistry and kinetics of shale conversion.
  - Continue evaluation of explosive fracture tests to provide guidance for new laboratory experiments.
  - Materials transport research, completion of evaluation of fracture test series, new laboratory research in support of fracture modeling and diagnostics, tests of hypotheses for new concepts.
  - Complete innovative concept studies regarding Eastern shales.

- o Environmental Mitigation .... $ 4.3
  - Continue laboratory research on chemistry and cleanup of water and air pollutants from retorting and maintain compliance activities.
  - Effects of process parameters on pollutant emissions, evaluation of data, and implementation of control technology tests at field sites.
  - Develop data to assist industry to mitigate problems regarding air emission control procedures, water management systems, and solid waste management strategies. Transfer retort abandonment models completed in FY 1983 to industry.

GAS

UNCONVENTIONAL GAS RECOVERY

(Budget Authority in Millions)

FY 1982	FY 1983	FY 1984 Request
$ 8.7	$13.9	$ 5.0

Natural gas currently supplies about 25 percent of the total energy consumed in the United States. For almost ten years, the annual addition of gas reserves from new discoveries has been less than the withdrawals from existing, proven reserves, although since the late 1970's the difference between withdrawals and additions has been steadily decreasing. This change is a result of increased exploration activity resulting from partial price decontrol. This trend has shown that considerable conventional shallow and deep gas may be available for immediate use, and that gas resulting from successful research on unconventional resources, combined with this conventional gas, represents a secure domestic supply that could meet the Nation's needs into the next century.

The Unconventional Gas Recovery program has the goal of assisting the private sector in developing cost-effective diagnostic and extraction technologies required to produce gas efficiently and economically from gas resources currently unrecoverable with state-of-the-art technology. Unconventional sources of gas typically include the eastern Devonian gas shales, western gas sands, methane from coalbeds, geopressured gas, methane hydrates, and abiogenic gas.

FY 1984 Budget ($ in Millions)

o Eastern Gas Shales	$ 1.0
- Continue integration of all shale data into the Eastern Gas Shales projects data base.	
o Western Tight Gas Sands	$ 3.0
- Continue multi-well experiment and supporting research including field testing and data analysis.	
o Environmental and Advanced Research	$ 1.0
- Characterization of gas resource potential of methane hydrates and deep source (abiogenic) gas, as well as data analysis of environmental assessments.	

PROGRAM DIRECTION

(Budget Authority in Millions)

	FY 1982	FY 1983	FY 1984 Request
Headquarters Program Direction	$13.8	$ 9.0	$ 7.9
ETC Program Direction	$ —	$30.0	TBD

The Headquarters staff is responsible for the overall direction of the Fossil Energy program. Activities include planning, budgeting, policy formulation and implementation, and program management, monitoring and evaluation.

The Energy Technology Center's staffs are responsible for executing day-to-day project management functions for assigned programmatic areas. Activities include contract monitoring, performance of technical evaluations, development of project and procurement plans, dissemination of technical data, and other activities related to program and site support.

By May 1, 1983, we expect the agreements to transfer the Laramie and Grand Forks Energy Technology Centers to the University of Wyoming and the University of North Dakota, respectively, to become effective. All real and personal property will be transferred to the universities within 60 days after the effective date of the agreements. The Department has negotiated with each university a provision that they will employ the bulk of the Federal employees so as to maintain the integrity of the Federally-funded research program at each site.

The Department is currently evaluating proposals received in response to a competitive solicitation for an operator for the Bartlesville Energy Technology Center. An agreement to transfer operating responsibility to a non-profit organization, under the guidelines of P.L. 97-394, is expected to be negotiated by early summer. The agreement will then be submitted to the Congress for a review of up to 30 days. The Bartlesville center would remain government-owned, and Federal financing of R&D would continue. The selected operator would be expected to share research costs on an increasing basis and would also be free to conduct research for sponsors other than the Department of Energy. The proposer must agree to provide current Federal employees at Bartlesville the right of first refusal to those positions for which they qualify and are needed by the operator.

The FY 1984 request submitted to the Congress on January 31, 1983, did not specify funding for the Energy Technology Center (ETC) indirect costs in the ETC Program Direction account as requested in the FY 1983 Appropriations Act. This amount is currently being identified within the $138 million budget request and will be provided to the Congress.

. The FY 1984 budget request also proposes a personnel level of 560 fulltime permanent employees for the Fossil Energy headquarters and field organization. We recognize that this is considerably below the floor of 754 fulltime permanent employees currently mandated by the Congress. The President's FY 1984 budget, as part of the section dealing with General Provisions for Department of Energy activities, proposes the repeal of the statutory provisions requiring that a specified number of Federal employees be maintained. We believe this is necessary to ensure that sufficient flexibility is maintained within the Department to conduct an efficient and cost-effective Federal program. We ask that the Congress favorably consider the repeal of these statutory provisions.

FY 1984 Budget ($ in Millions)

o Provide funds for salaries, benefits, and travel for Fossil Energy Headquarters personnel during FY 1984	$ 7.9

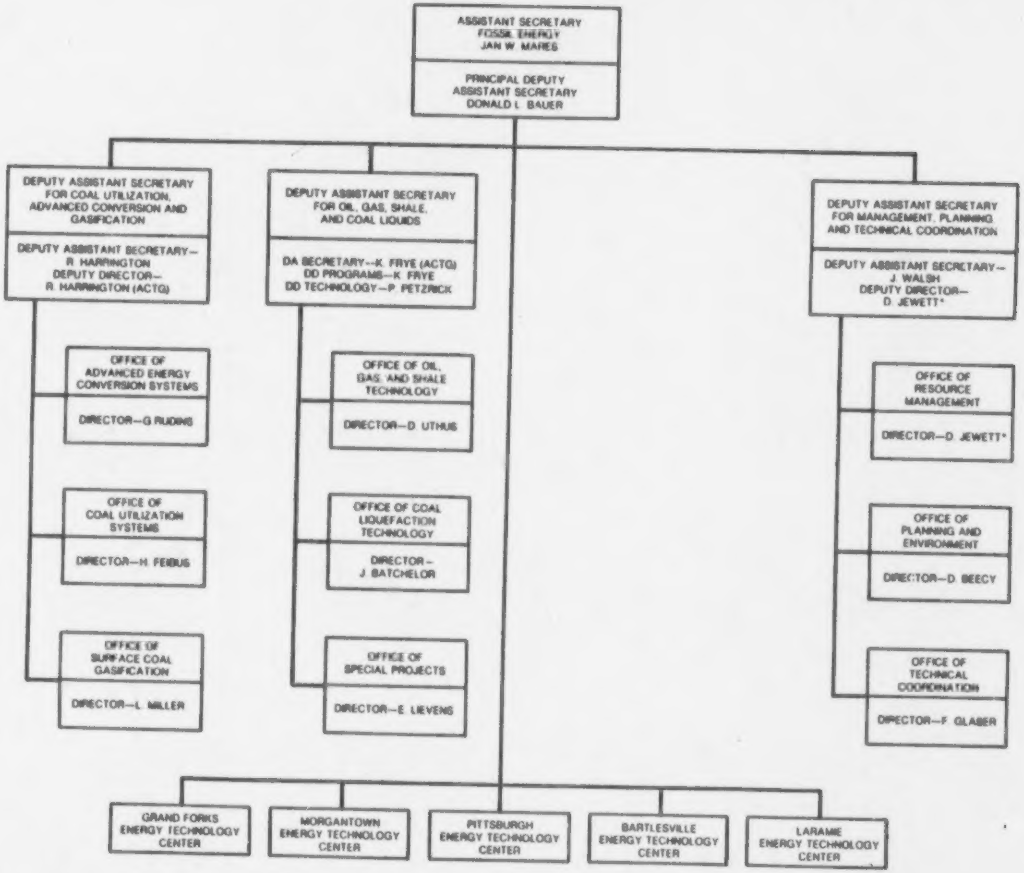
CONCLUSION

The current period of relative price moderation provides this Nation the time and opportunity to establish a sound base of technological understanding and to conduct the necessary research and development of new innovations and more cost-effective technologies that will be needed by future generations. It also provides an opportunity to develop the information needed to help mitigate environmental concerns associated with a transition to new energy systems.

The budget and the programs described will help produce the information that will be fundamental to the development of new, improved energy systems. This, we believe, is an appropriate use of public funds. By carefully focusing the Federal R&D program on the development of technologically sound data bases, rather than funding the scale-up of specific processes that may benefit only individual companies, we believe Government can play a useful role that will complement, rather than compete with, private sector initiatives.

Within the context of the budgetary constraints made necessary by the President's economic recovery program, the Fossil Energy budget proposed for FY 1984 represents a realistic approach toward fostering the technological advances needed for the future.

OFFICE OF FOSSIL ENERGY


ASSISTANT SECRETARY
FOSSIL ENERGY
JAN W. MARES
PRINCIPAL DEPUTY
ASSISTANT SECRETARY
DONALD L. BAUER
DEPUTY ASSISTANT SECRETARY
FOR COAL UTILIZATION,
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GASIFICATION
DEPUTY ASSISTANT SECRETARY—
R. HARRINGTON
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OFFICE OF
ADVANCED ENERGY
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SYSTEMS
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PITTSBURGH
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CENTER
BARTLESVILLE
ENERGY TECHNOLOGY
CENTER
LARAMIE
ENERGY TECHNOLOGY
CENTER

*DUAL POSITION

APPROVED OCTOBER 13, 1982

Senator **Warner**. Mr. Ford, I will defer to you if you would like to open up.

Senator **Ford**. Sometimes I would rather close than open up. I have several questions, and I don't believe we are going to be pushed this morning, so if you don't mind, may we just take our time?

Senator **Warner**. Sure.

Senator **Ford**. Any time you wish to cut in, I have about a dozen questions I would like to ask.

In your prepared statement you say on page 1 that the President has emphasized the need for a freeze on the aggregate of the nondefense discretionary programs, including the energy-related R&D programs, in fiscal year 1984 relative to the 1983 appropriations.

Mr. **Mares**. Yes, sir.

Senator **Ford**. If you follow that philosophy with respect to the fossil programs, namely, level funding, then your budget request for 1984 would be $312 million and not $138.1 million, of which only $94 million is new budget authority.

Why is it necessary to put the fossil programs well below 1983 appropriation level?

Mr. **Mares**. The President's judgment is that the aggregate of the discretionary nondefense programs should be level funded from fiscal year 1983 to fiscal year 1984. The budget reflects some areas where there will be increases and some areas where there will be decreases. When all of the programs and the needs were evaluated, the judgment was made that the best balance of trying to serve those needs was reflected by a lower request for fossil energy for 1984 than had been appropriated in 1983.

Senator **Warner**. I will have to interject. Let's ask him what was the Department's request to OMB?

Senator **Ford**. What was your request?

Mr. **Mares**. The Department request to OMB was $238 million for fossil energy.

Senator **Ford**. They just cut $100 million off of it?

Mr. **Mares**. Well, I think all agencies at all levels request from their superiors more funds than they expect to receive, and that is indicative of a very normal budgeting process. This technique allows the manager of whatever aggregate program is being evaluated to consider more options for allocations of resources. So it does not at all surprise me that when the fiscal year 1984 fossil energy budget request was submitted to OMB and evaluated against others, it was determined that the budget level should be less than the request that was made.

Senator **Ford**. Where is the other $173.9 million that was appropriated for fossil fuels, fossil programs? If you are going to level funding in 1984, where is the other approximately $174 million going?

Mr. **Mares**. Within the Energy Department there are areas which increased, for instance, the general science and energy research area.

Senator **Ford**. Concentrating on basic science of what?

Mr. **Mares**. Chemistry, physics, high energy physics.

Senator **Ford**. Fission, fusion; 87 percent of the R&D budget is going into those two operations, 7 percent to fossil.

Mr. **Mares**. That is correct. What I was suggesting is that there are increases even within the Department of Energy.

Senator **Ford**. Sure. I get the old story there is $20 million more than you recommended last time but it is a $200 million cut from what was appropriated. There was $108 million in 1983 requested, and we appropriated $312 million, and then it is $20 million more than requested last time. It sounds like you are asking for more when we are really cutting it about $200 million.

Mr. **Mares**. There is no question that, the request this year is less than what was appropriated by Congress for 1983. That is correct.

Senator **Ford**. Fine. That's all I want. I'm getting tired of saying we are requesting $20 million more than we requested last time. Sure, but you have $200 million cut.

Senator **Warner**. You know, those of us who sit on the military committees have an ability to look at the importance of energy to the military program as being just as critical as any tank or B-1. We fought, this Nation fought World War II primarily with its own fossil fuel resources, as we did Korea, and largely Vietnam, and in the foreseeable future the next few years, if we have the misfortunate of a comparable military contingency, we will have to again resort to fossil fuel because we are a long way from trying to support a military effort on any fission or fusion.

Mr. **Mares**. That is correct.

Senator **Warner**. And the driving force to reduce this was the military budget. It may well be we have to go back and rethink this because many times have I heard my distinguished colleague Senator Jackson say that the connection between energy and our military national defense is just one and the same.

We are putting you on the spot. We are making our point clear to those who are listening.

Mr. **Mares**. I don't think there is any disagreement about the importance of energy either to the domestic economy or to the defense of this Nation.

Senator **Warner**. And fossil particularly for military because that is an immediate response that we would have to make.

Mr. **Mares**. Absolutely, and as a liquid fuel it is very important. It is one of the reasons that within our own budget we have concentrated about 60 percent of our effort in order to enhance our technology base regarding liquid fuel.

You pointed out in your opening remarks the importance of encouraging our knowledge base to be able to extract more than just 25 percent of the oil that we know is in place, and in fact we do.

Senator **Warner**. Have you got adequate R&D funding money to go after that 75 percent remaining?

Mr. **Mares**. In consideration of all of the needs for the country, I think we have an adequate budget, yes, sir.

Senator **Warner**. Was the thrust of your original submission to OMB for energy research different than what is presented to us today? Did it make a change in the general approach of DOE when they took out $100 million? Did they just scale everything back a little bit or just say no, we will stop in certain major areas and put your emphasis in others?

Did OMB redirect your thrust in R&D for fossil?

Mr. **Mares**. The difference is more a question of level of activity than a fundamental direction.

Senator **Warner**. What was the major part that dropped out then when you lost, as Senator Ford pointed out, the $100 million?

Mr. **Mares**. I did not bring the table with me. I think we have provided copies of the fiscal year 1984 fossil energy budget request to OMB to you, sir. I don't remember the difference between what was requested in each of the line items to OMB versus what we are requesting at this stage. We would be happy to provide you that information.

[The information follows:]

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DEPARTMENT OF ENERGY
FY 1984 CONTROL TABLE
(DOLLARS IN THOUSANDS)

BY APPROPRIATION

PAGE 26

A/S CODE	ACCOUNT TITLE	FY 1983 IN FY84 STR B/A	FY 1984 ASST. SEC. B/A	FY 1984 DEPT. REQ. B/A	FY 1984 CONG. B/A
992300	FOSSIL ENERGY				
59003	GENERAL REDUCTION....................................	—	—	—	—
59005	COAL				
59009	MINING R&D				
59010	OP. EXP. & CAP. EQUIP................................	—	—	—	—
59011	CONSTRUCTION...	—	—	—	—
59012	TOTAL, MINING R&D....................................	—	—	—	—
59014	COAL LIQUEFACTION				
59015	OP. EXP. & CAP. EQUIP................................	37,600	42,400	41,400	17,000
59016	CONSTRUCTION...	—	—	—	—
59017	TOTAL, COAL LIQUEFACTION.............................	37,600	42,400	41,400	17,000
59019	SURFACE COAL GASIFICATION				
59020	OP. EXP. & CAP. EQUIP................................	39,000	27,540	27,090	16,900
59021	CONSTRUCTION...	—	—	—	—
59022	TOTAL, SURFACE COAL GASIFICATION.....................	39,000	27,540	27,090	16,900
59024	UNDERGROUND COAL GASIFICATION				
59025	OP. EXP. & CAP. EQUIP................................	6,000	2,000	2,000	2,000
59026	CONSTRUCTION...	—	—	—	—
59027	TOTAL, UNDERGROUND COAL GASIFICATION.................	6,000	2,000	2,000	2,000
59029	ADV. RESEARCH & TECHNOLOGY DEV				
59030	OP. EXP. & CAP. EQUIP................................	33,150	44,320	41,320	25,500
59031	CONSTRUCTION...	2,800	8,040	8,040	5,040
59032	TOTAL, ADV. RESEARCH & TECHNOLOGY DEV................	35,950	52,360	49,360	30,540
59069	CONTROL TECHNOLOGY & COAL PREPARATION				
59070	OP. EXP. & CAP. EQUIP................................	27,900	26,300	25,000	17,050
59071	CONSTRUCTION...	—	—	—	—
59072	TOTAL, CONTROL TECHNOLOGY & COAL PREPARATION......	27,900	26,300	25,000	17,050

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DEPARTMENT OF ENERGY
FY 1984 CONTROL TABLE
(DOLLARS IN THOUSANDS)

BY APPROPRIATION
PAGE 27

A/S CODE	ACCOUNT TITLE	FY 1983 IN FY84 STR B/A	FY 1984 ASST. SEC. B/A	FY 1984 DEPT. REQ. B/A	FY 1984 CONG. B/A
50074	HEAT ENGINES AND HEAT RECOVERY				
50075	OP. EXP. & CAP. EQUIP..............................	5,000	6,000	6,000	1,000
50076	CONSTRUCTION......................................	—	—	—	—
50077	TOTAL, HEAT ENGINES AND HEAT RECOVERY..............	5,000	6,000	6,000	1,000
50084	COMBUSTION SYSTEMS				
50085	OP. EXP. & CAP. EQUIP..............................	24,200	20,200	16,700	8,400
50086	CONSTRUCTION......................................	—	—	—	—
50087	TOTAL, COMBUSTION SYSTEMS..........................	24,200	20,200	16,700	8,400
50094	FUEL CELLS				
50095	OP. EXP. & CAP. EQUIP..............................	30,050	22,500	20,500	9,500
50096	CONSTRUCTION......................................	—	—	—	—
50097	TOTAL, FUEL CELLS..................................	30,050	22,500	20,500	9,500
50109	MAGNETOHYDRODYNAMICS				
50110	OP. EXP. & CAP. EQUIP..............................	29,000	—	—	—
50111	CONSTRUCTION......................................	—	—	—	—
50112	TOTAL, MAGNETOHYDRODYNAMICS........................	29,000	—	—	—
50205	ETC PROGRAM DIRECTION - COAL.......................	23,700	—	—	—
50120	PROGRAM DIRECTION - COAL...........................	8,200	5,400	7,265	7,060
50125	CAPITAL EQUIPMENT - COAL...........................	—	—	—	—
50130	SUBTOTAL, COAL.....................................	266,600	204,700	196,065	109,450

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DEPARTMENT OF ENERGY
FY 1984 CONTROL TABLE
(DOLLARS IN THOUSANDS)

BY APPROPRIATION

PAGE 28

A/S CODE	ACCOUNT TITLE	FY 1983 IN FY84 STR B/A	FY 1984 ASST. SEC. B/A	FY 1984 DEPT. REQ. B/A	FY 1984 CONG. B/A
50135	PETROLEUM R&D				
50149	ENHANCED OIL RECOVERY				
50150	OP. EXP. & CAP. EQUIP..............................	6,500	13,300	12,300	11,250
50151	CONSTRUCTION..	—	—	—	—
50152	TOTAL, ENHANCED OIL RECOVERY......................	6,500	13,300	12,300	11,250
50154	OIL SHALE				
50155	OP. EXP. & CAP. EQUIP..............................	12,250	14,400	12,900	8,600
50156	CONSTRUCTION..	—	—	—	—
50157	TOTAL, OIL SHALE....................................	12,250	14,400	12,900	8,600
50144	DRILLING AND OFFSHORE TECHNOLOGY				
50145	OP. EXP. & CAP. EQUIP..............................	—	—	—	—
50146	CONSTRUCTION..	—	—	—	—
50147	TOTAL, DRILLING AND OFFSHORE TECHNOLOGY............	—	—	—	—
50139	ADVANCED PROCESS TECHNOLOGY				
50140	OP. EXP. & CAP. EQUIP..............................	5,000	6,000	6,000	2,900
50141	CONSTRUCTION..	—	—	—	—
50142	TOTAL, ADVANCED PROCESS TECHNOLOGY.................	5,000	6,000	6,000	2,900
50207	ETC PROGRAM DIRECTION - PETROLEUM..................	3,450	—	—	—
50160	PROGRAM DIRECTION - PETROLEUM......................	600	500	500	600
50165	CAPITAL EQUIPMENT - PETROLEUM......................	—	—	—	—
50170	SUBTOTAL PETROLEUM..................................	27,800	34,200	31,700	23,350

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DEPARTMENT OF ENERGY
FY 1984 CONTROL TABLE
(DOLLARS IN THOUSANDS)

BY APPROPRIATION

PAGE 29

A/S CODE	ACCOUNT TITLE	FY 1983 IN FY84 STR B/A	FY 1984 ASST. SEC. B/A	FY 1984 DEPT. REQ. B/A	FY 1984 CONG. B/A
50175	GAS				
50179	UNCONVENTIONAL GAS RECOVERY				
50180	OP. EXP. & CAP. EQUIP.	13,900	11,000	11,000	5,000
50181	CONSTRUCTION	——	——	——	——
50182	TOTAL, UNCONVENTIONAL GAS RECOVERY	13,900	11,000	11,000	5,000
50208	ETC PROGRAM DIRECTION - GAS	2,850	——	——	——
50185	PROGRAM DIRECTION - GAS	200	100	100	200
50190	CAPITAL EQUIPMENT - GAS	——	——	——	——
50200	SUBTOTAL - GAS	16,950	11,100	11,100	5,200
50210	ENERGY TECHNOLOGY CENTER	——	——	——	——
50212	COMMERCIALIZATION STUDIES	——	——	——	——
50265	TOTAL, FOSSIL ENERGY	311,350	250,000	238,865	138,000
50258	USE OF UNOBLIGATED BALANCES - FE (FE)	-93,836	——	——	-31,000
50260	TRANSFER FROM ALT. FUELS - FE (FE)	——	——	——	-13,000
50261	FY1981 DEFERRAL - FE (FE)	——	——	——	——
50262	FY1981 DEFERRAL - FE (FE - CONST)	——	——	——	——
992590	TOTAL, FOSSIL ENERGY	217,514	250,000	238,865	94,000
992591	(OP. EXP. & CAP. EQUIP.)	214,714	241,960	230,825	88,960
992592	(CONSTRUCTION)	2,800	8,040	8,040	5,040

Senator WARNER. Did the fossil bear an undue penalty in this cutback?

Mr. MARES. I would suggest not. I think that the issue is the evaluation process of a large number of needs both within the energy environment as well as external to the energy environment in this country and trying to decide what is the appropriate level of funding. During the process, very difficult judgments are made, and in the final sum when those needs were evaluated, I am comfortable with the judgment on our request for fossil energy.

Senator FORD. At the 41st annual meeting of the Institute of Gas Technology, they report through "Gas Scope" an article by Dr. D. S. Lee on excellence in energy research and development.

Have you read that article?

Mr. MARES. I don't believe I have read that. I know Dr. Lee, and I have read some things he has written, sir.

Senator FORD. Do you basically agree with his philosophy or disagree with it?

Mr. MARES. Well, without knowing specifically what literal question are you going to ask me——

Senator FORD. I'm just trying to lead you up the path here.

Mr. MARES. I'm well aware of that, sir.

Senator FORD. Let me follow up on Senator Warner's question. He says, "No one denies that energy, whether from finite resources or from renewable resources, is as fundamental to our self-preservation as a strong national defense. Energy cannot be left to the private sector alone because national needs and priorities do not enter into private sector decisions," and so it gets back to the proposition it might be nice for you to read that. It has some interesting statements.

Mr. MARES. I agree with that statement, and I am sure the Senator agrees with that statement. What we are discussing is not whether we agree or disagree with the statement. The judgment is what level of Federal funding is appropriate in the context of satisfying that need in the context of all the needs that the Federal Government must address.

Senator FORD. Let me get on with some other questions that I wish to get into before I run out of time. On page 2 of your statement you show a chart entitled, "Technology Development Path," and you explain how the DOE fiscal year 1984 budget is oriented toward the applied research portion of the technology development path.

Mr. MARES. Yes, sir.

Senator FORD. Where is the Clinch River breeder reactor project on this chart?

Mr. MARES. The Clinch River breeder reactor is between proof of concept and process development. It is for sure not commercialization.

Senator FORD. That is basically where it is then. You don't show it in here, but it would be somewhere in between. You don't have anything in between, but is it proof of concept or process development?

Mr. MARES. It is probably more in the process development than the proof of concept.

Senator **Ford**. On page 20 of your statement you note that your proposed personnel level of 560 full-time permanent employees is well below the congressionally mandated level of 754, and that you will seek an amendment in the law to permit the lower staffing level.

What is your current staffing level?

Mr. **Mares**. Our total is 917 full-time permanent employees and 97 other-than-fulltime employees, as of March 20, 1983.

Senator **Ford**. About 900; if you do not obtain the requested amendment, will you comply with the law?

Mr. **Mares**. I have sworn to do so, sir. I would say there are some subelements in terms of the minimum staffing required by law such as the Morgantown Technology Center as well as headquarters, where the targets were higher than the staffing at the time targets were established.

I cannot report to you that we have yet achieved those targets. In the case of headquarters, we have had a much higher attrition than we had ever expected. We have hired about I believe 13 people and lost 13 people, so we are basically at the 135 level that was in effect at the time the law was enacted. At Morgantown, we have increased from about 181 at the time, the law was enacted to 211 as of March 20, 1983. We have had over 1,000 applications. We are evaluating people, have offers outstanding, and are moving I think in an intelligent and responsible way to comply, but in neither of those cases can I say that we are yet in compliance.

In the total we are in compliance, but I would respectfullv request the Congress to consider at least a reduction in those floors. A floor makes it very difficult for a manager to operate.

Senator **Ford**. No, it doesn't now. Let me get back to a point. If we take those floors off, we find that you will do whatever you darn well please, hire whichever direction you want to go. For Congress one way to hold a mandate on what they think is to keep personnel in an area, to keep the research and development going without allowing you to deplete the personnel in one area and increase it in another so that the proposal from Congress is one—we had them tell us last year you may appropriate, sir, but we won't spend it. We had that last year, and I don't particularly like that.

Mr. **Mares**. I thought, sir, in our area——

Senator **Ford**. I didn't say you now, but I just say that we were told last year by testimony in this committee you can appropriate. We won't spend it.

Mr. **Mares**. With respect to fossil energy, we will spend money that we are appropriated unless and until we send up a deferral or a rescission notice that allows Congress to have the opportunity to appropriately respond.

Regarding the levels of personnel in fossil energy, we estimated that over half of our funds are expended through industrial corporations. About a fifth has been at the Energy Technology Centers, about 12 percent at the national laboratories, and about 8 percent at the universities. The number of people that are legally required in fossil energy is not a factor in deciding either the quality of work we do or the quantity of work. It is very important, I believe, that we continue to use the industrial firms, universities and national labs. In the final analysis, the results of our work are going to be taken by industry and used in the commercial sector.

Senator **Ford**. Let me ask you then how much of your R&D budget will be spent in the universities in 1984?

Mr. **Mares**. Well, in fiscal year 1983 it is about 8 percent.

Senator **Ford**. About 8 percent?

Mr. **Mares**. It is about 8 percent.

Senator **Ford**. Ninety-two percent spent some place else?

Mr. **Mares**. That is correct. About 92 percent will be spent elsewhere.

Senator **Ford**. Where else?

Mr. **Mares**. About 12 percent in the national labs, about 22 percent at the ETC's, and the remainder primarily in industrial firms; now in the 1984 request we have not made final decisions on the allocation but I would expect that we would continue to use all four of those institutional types because I think they all have a role to play.

Senator **Ford**. Well, you explained ETC's a little bit in your opening statement, but you had $30 million in 1983 for technology centers and zero in 1984, and the last sentence on page 19 wherein your $138 million includes the money for the technology centers——

Mr. **Mares**. The 30 million that we are talking about are for the indirect costs at the center. They are support costs, not the R&D that is done specifically at the center.

Since the transmittal of the fiscal year 1984 OMB budget to your committee and others, we have the allocation of the fiscal year 1984 ETC indirect costs or the program direction to the various programs and have shown where it was within the total $138 million. When we prepared the original fiscal year 1984 budget of $138 million, we did not have in place readily the ability to allocate by program or reduce from the individual program lines the expenditures that are included within program direction.

Senator **Ford**. You propose to spend only $1 million for atmospheric fluidized bed combustion activity in 1984, and over three times as much for pressurized fluidized bed combustion.

Does this indicate your view of the relative potential for these two technologies?

Mr. **Mares**. It recognizes what we think are the activities in each of those technologies that are appropriate for us to be continuing to fund to enhance the development of each of them.

Senator **Ford**. To enhance the development of each of them?

Mr. **Mares**. Yes, sir.

Senator **Ford**. Well, which is the closest to becoming commercial?

Mr. **Mares**. Atmospheric fluidized bed.

Senator **Ford**. Does it need a push?

Mr. **Mares**. Well, there are some things which we think are important to continue to do technology development on, and we have requested funds to take one of the advanced concepts and have it tested at bench scale.

Let me ask one more question, Mr. Chairman, and this will be my final question unless I think of some.

On page 14, enhanced oil recovery is the only fossil item up over 1983. You are going to tell me I'm wrong?

Mr. **Mares**. Well, there are at least two coal-related items that are increased. One is the university coal research program, and if I am not mistaken, I thought that flue gas cleanup was also higher. I think we requested $7.6 million in fiscal year 1984 and were appropriated $7 million in fiscal year 1983, but in terms of the large line items, you are correct. It is the only one that was increased.

Senator **Ford**. Substantially, from $6.5 million to $11.25 million.

Mr. **Mares**. That is correct.

Senator **Ford**. I'm all for enhanced oil recovery, but is this any more generic or long-range research than fossil items cut or phased out?

Mr. **Mares**. Yes.

Senator **Ford**. Why?

Mr. **Mares**. Basically that increase is oriented toward university work, to understand the characteristics of the reservoir, the properties, the geophysical, geochemical properties in the reservoirs. This is necessary in order for the technology to be developed to produce processes which are not commercial today. This could enable us to ultimately extract the two-thirds to three-quarters of oil that we know exists, but that we can't get out of the ground today—we as a nation.

Senator **Ford**. Well, you encourage this direction. We might encourage in some others. The Department of Energy has an Energy Research Advisory Board?

Mr. **Mares**. Yes, sir.

Senator **Ford**. Consisting of notables, particularly notable in the scientific arena and energy research, and they advise the Department on how DOE should be spending its research dollars most effectively, as I understand it.

The Energy Research Advisory Board just released a report on energy conservation research. I am not sure you like what they said, but would it be appropriate for this Board to evaluate your fossil energy research programs?

Mr. **Mares**. It could be done. I think we get evaluation by a whole host of institutions already. I mean we have discussions with EPRI, GRI and other groups about our programs.

The Energy Research Advisory Board is a Board of advisers available to the Department——

Senator **Ford**. Isn't this really yours?

Mr. **Mares**. No.

Senator **Ford**. Didn't you appoint them?

Mr. **Mares**. You mean did the Office of Fossil Energy? No, sir.

Senator **Ford**. Who appointed them?

Mr. **Mares**. They are appointed by the Secretary of Energy.

Senator **Ford**. Well, it is the Energy Department?

Mr. **Mares**. Yes, sir.

Senator **Ford**. They are yours then indirectly?

Mr. **Mares**. Well, they are appointed by the Department.

Senator **Ford**. OK. You are part of the Department, aren't you?

Mr. **Mares**. Yes, sir.

Senator **Ford**. Then this Board is yours.

Mr. **Mares**. Yes, sir.

Senator **Ford**. And what do you think about asking them to evaluate your fossil energy research program?

Mr. **Mares**. I am not sure of the various programs and evaluations that they have underway as of this moment and don't know what their particular workload is.

Senator **Warner**. That's a good bureaucratic answer, but it is up to us to get that thing done.

Senator **Ford**. Thank you, Mr. Chairman.

Senator **Warner**. In that context, on the assumption that this committee is more likely to authorize funds over and above the request here, where would you suggest by way of priority that we put those funds?

Mr. **Mares**. Well, I have not tried to evaluate that question.

Senator **Warner**. Then will you and give us some assistance?

Mr. **Mares**. Well, if there is a specific question on a specific project or technology, I will provide you with our professional judgment about the——

Senator **Warner**. Prioritization of the need for additional funds.

Mr. **Mares**. Relative to that, I am not sure I can be forthcoming, Mr. Chairman. We have provided the information regarding the request that was made to OMB in some detail.

Senator **Warner**. I know a way to get that done. Mr. Melcher, I yielded to my colleague from Tennessee, so I will take a few minutes here and then we will shift.

Now you are preparing to turn over the Grand Forks Energy Technology Center and the Laramie Energy Technology Center to universities, is that correct?

Mr. **Mares**. That is correct.

Senator **Warner**. You also are proposing to transfer operating responsibility of the Bartlesville Center to a private nonprofit corporation?

Mr. **Mares**. That is correct.

Senator **Warner**. What commitment will the Department of Energy have to make in terms of creating funds for these facilities over the next 5 years in order to accomplish this transfer?

Mr. **Mares**. In the Bartlesville case, we have proposed in the request for proposals that the funding, subject to appropriation, in the first year will be at a level of $9 million and in the second year $8 million,in the next $7 million, $6 million, and $5 million over a 5-year period.

In the Grand Forks and Laramie cooperative agreements, which have been executed the Grand Forks agreement is 3 years in duration, and its funding level was about $7.2 million in the first year, $6.8 in the second, $6.5 in the third. In the case of Laramie, it was a 3½-year agreement and that contemplated funding of about $8.08 in the first year, $7.7 in the second, and $7.3 in the third, and $3.6 in the fourth year for one-half year of operation.

Senator **Warner**. Can you give us a breakout of coal research funds in this amount of funding and supply that for the record?

Mr. **Mares**. We will go into that cooperative agreement and make a judgment as to how much would be coal related, yes, sir.

Senator **Warner**. Likewise oil research?

Mr. **Mares**. Yes. We did not request in the budget formal amounts for those two agreements. They are included within the request under the programmatic line items, so within the combination of advanced process technology enhanced oil recovery, the oil shale, and the coal budget, there are adequate funds for us to be able to comply with the agreements, live up to the agreements that we have negotiated, and will negotiate at Bartlesville.

[Subsequent to the hearing Mr. Mares supplied the following:]

Cooperative Agreement Commitments for GFETC, LETC and BETC

Cooperative agreement commitments for the Grand Forks, Laramie, and Bartlesville Energy Technology Centers are reflected in the attached chart.

DEPARTMENT OF ENERGY

COOPERATIVE AGREEMENT COMMITMENTS
FOR
GFETC, LETC AND BETC
($ in thousands)

3/29/83

	GFETC				LETC				BETC			
YEAR	AA COAL	AC PETROLEUM	AB GAS	TOTAL	AA COAL	AC PETROLEUM	AB GAS	TOTAL	AA COAL	AC PETROLEUM	AB GAS	TOTAL
1st	7200			7200	1617	6465		8082		9000		9000
2nd	6800			6800	1535	6143		7678		8000		8000
3rd	6500			6500	1458	5836		7294		7000		7000
4th	-			-	730	2918		3648		6000		6000
5th	-			-				-		5000		5000
TOTAL	20500	0	0	20500	5340	21362	0	26702	0	35000	0	35000

Senator **Warner**. The research performed at these energy technology centers subsequent to the transfer, will it be treated as all the research that is federally supported?

Mr. **Mares**. I am not sure I understand.

Senator **Warner**. In other words, will the data be available to the public?

Mr. **Mares**. Absolutely; For the part that we fund, it is our purpose to obtain the information and to make it available broadly.

Senator **Warner**. You have justified the increased request in the petroleum research on the basis of it is an enhanced potential resource awaiting recovery by advanced processes.

Could you give the subcommittee some idea of the potential resource of gas from unconventional sources?

Mr. **Mares**. I will supply it for the record. It is enormous, particularly in the tight sands and the other sands that we are working on with the Devonian shales. The resource is many times the currently proved resource within this country.

[The information follows:]

POTENTIAL RESOURCE OF GAS FROM UNCONVENTIONAL SOURCES

Unconventional gas resource estimates vary extremely widely with some numbers fairly firm and others speculative. The summed total of unconventional gas resource estimates for non-speculative gas resources (those currently being produced or measured in some manner) range from 350 to 1150 trillion cubic feet while the speculative resource (those with estimates based on inferred or indirect measurements) estimates are up to 270 million trillion cubic feet.

Senator **Warner**. How much of the potential resource is attributed to the western gas sands methane and coal beds, geopressurized gas methane hydrates, and eastern Devonian gas shale?

Mr. **Mares**. We would supply that for the record. Some of those may not be known, particularly with methane hydrates. This is another species of material which has really only been physically seen within the last 5 years and it is basically methane in ice. It is found in the seabeds and found in the permafrost, so what we are trying to do is decide, make judgments about what is the potential of that resource.

[The information follows:]

UNCONVENTIONAL GAS RESOURCES

Resource estimates of the unconventional gas resources fall into two broad areas; non-speculative (those currently being produced or measured in some manner) and speculative (those with estimates based on inferred or indirect measurements). The size of each resource is shown in the following table:

Nonspeculative: Trillion cubic feet (TCF):	
Western gas sands	50-600
Methane from coalbeds	300-500
Eastern Devonian Shales	0- 50
Speculative Resources: TCF:	
Geopressured gas	3000-59000
Methane hydrates	[1] 1.1×10^5-2.7×10^8

[1] 110 thousand-270 million trillion.

Senator **Warner**. Will my colleague from Montana be dealing with the Great Plains coal project or is that in your area of questioning?

Senator **Melcher**. No, it isn't.

Senator WARNER. I was going to ask can you give us an update on the Great Plains coal project?

Mr. MARES. Yes, sir. We are monitoring that project.

Senator WARNER. How will the falling oil price affect the price of gas produced at this project?

Mr. MARES. Well, formulas for the sale of gas from that project are related to the price of No. 2 fuel oil and natural gas at the time that those sales take place, and so if the prices when those products are sold are lower than were expected, it will mean lower revenues than were originally expected.

Senator WARNER. Senator Melcher.

Senator MELCHER. Dr. Mares, your statement on MHD on page 14 continues the same line as the Department of Energy has had for the past 2 years. That is the phaseout of the MHD program. However, that has been blocked by congressional action, and as a matter of fact, the amount of funds available for the fossil fuel research and development was appropriated I believe for this fiscal year at $312 million.

Is that about right?

Mr. MARES. Yes, sir.

Senator MELCHER. And so the administration budget for fossil fuels research and development is, I believe, $138 million, but you are only asking for new budget authority for $94 million, and perhaps you have answered earlier what happened to the other $44 million. Is that part of the record?

Mr. MARES. Those funds are available because of appropriations in years before 1983 on activities that were concluded at funding levels less than the level that was appropriated, and so we are requesting application of those funds to the 1984 budget request.

Senator MELCHER. So if you spent what you have planned, then it would be about $138 million?

Mr. MARES. Yes, sir.

Senator MELCHER. For fiscal year 1984, and none of it would be for MHD?

Mr. MARES. Yes, sir.

Senator MELCHER. Now you say that MHD has high risk and much higher cost relative to other advanced electricity generating technologies now under development.

Which of those would apply to central base power generation of electricity comparable to what MHD would apply to?

Mr. MARES. Pressurized fluidized bed technology and combined cycle gas turbines as well as fuel cells all could be available for centralization.

Senator MELCHER. Let's take one at a time. First of all, the first that you referred to, what stage is the R&D there and how much do you project the funds to be and what are the capabilities projected, if successful?

Mr. MARES. The funding that we are requesting on pressurized fluidized bed combustion is $3.4 million in fiscal year 1984.

Senator MELCHER. For what?

Mr. MARES. Pressurized fluidized bed combustion.

Senator MELCHER. $5 to $6 million?

Mr. MARES. $3.4 million is requested for fiscal year 1984.

Senator **Melcher**. Can you deliver us the schedule of what this would accomplish and when it might be generating electricity?

Mr. **Mares**. I would prefer to supply for the record the guesses as to when it would be available for the commercial utilization.

[The information follows:]

ACCOMPLISHMENTS IN PRESSURIZED FLUIDIZED BED COMBUSTION AND TIMETABLE FOR COMMERCIALIZATION

Pressurized fluidized bed [PFB] technology base activities, consisting of a long-term materials program and evaluation of combustion characteristics of a wide range of coal feeds (liquids, coal-water mixtures), will continue. The proposed fiscal year 1984 funding will continue engineering studies and evaluation of advanced PFB concepts. The advanced PFB program was initiated in 1983, following a solicitation to industry for new concept definitions.

If PFB projects presently underway at Curtiss-Wright, Grimethorpe and the American Electric Power Company are successful, commercialization could occur in the early 1990's.

Mr. **Mares**. There is a demonstration, a large pilot plant demonstration concept that is under consideration involving the American Electric Power Co.

Senator **Melcher**. Which one?

Mr. **Mares**. The American Electric Power Co. In addition, there is an operating pressurized fluidized bed boiler in England at Grimethorp called the Grimethorp project. The testing of the unit will come to completion in terms of the Federal Government role during early fiscal year 1984 based upon fiscal year 1983 funding.

Senator **Melcher**. Now are you referring to the——

Mr. **Mares**. The Grimethorpe project; I am suggesting that there are pressurized fluidized bed pilot plants that the Federal Government has funded through to operation. In the case of Curtiss-Wright, the facility is under construction with operation scheduled for early 1984.

Senator **Melcher**. What is the advantage of that technology?

Mr. **Mares**. Well, the advantage is it combusts coal more cleanly as well as on a more economic or thermally efficient basis than the traditional pulverized coal burners.

Senator **Melcher**. You mean—could you relate it to cost per kilowatt hour?

Mr. **Mares**. I don't have that information in my head. We will supply it for the record.

[The information follows:]

ESTIMATED ECONOMICS OF PRESSURIZED FLUIDIZED BED COMBUSTION

An EPRI report prepared in 1980, "Preliminary Assessment of Alternative PFBC Power Plant Systems," compared the economics of pressurized fluidized bed combustion with a reference pulverized coal facility. The results are summarized below:

	Total capital requirements $KW	Levelized busbar power cost Mills/KWh
Reference PCF plant (with scrubber)	734	50.3
PFB combined cycle plant (steam cycle)	669	46.2

The analysis assumed the size was nominal 1000 MWe consisting of appropriately sized modular units. The capital costs are in mid-1978 dollars and the power costs are levelized over 30 years.

In 1979, the Department of Energy performed an independent assessment of the Pressurized Fluidized Bed Combustion program. The findings of this assessment are in agreement with the EPRI report.

Senator MELCHER. Is it like what it costs now?

Mr. MARES. Well, I certainly don't think so, sir.

Senator MELCHER. It is considerably higher?

Mr. MARES. Quite the contrary; our judgment is that it would be more economically efficient than what we have today. That is the rationale for providing support for that technology.

Senator MELCHER. That is about $5 or $6 million?

Mr. MARES. I think it is $3.4 million.

Senator MELCHER. All right, so you are about done with it?

Mr. MARES. We are not funding at a high level. We are trying to do the basic applied research in support of that technology, yes, sir.

Senator MELCHER. Now the second one that you mentioned?

Mr. MARES. The one that is probably the closest to commercial fruition is the gasification combined cycle facilities. An example is a facility in Cool Water in southern California that EPRI, Southern Cal Edison, Texaco, General Electric, Bechtel, and a Japanese group are funding which is based upon a Texaco gasifier and a gas turbine. When it is finally developed this process should combust coal in a more cost-effective, environmentally acceptable way than the standard form of burning coal today.

Senator MELCHER. And therefore it is more cost-effective?

Mr. MARES. Yes, sir.

Senator MELCHER. How much money are you putting into that?

Mr. MARES. We don't have any money in that.

Senator MELCHER. Then that is something you are not doing now?

Mr. MARES. That is correct.

Senator MELCHER. So then the third one?

Mr. MARES. The third one are the fuel cells, the phosphoric acid-based fuel cells for utility applications, and the total request is $9.5 million. As I recollect, the request for the phosphoric acid is about $3 million. We expect to conclude the 4.8 megawatt demonstration at Con Edison in New York, with fiscal year 1983 funding, and that would conclude the demonstration program for centralization powerplants.

Senator MELCHER. All right. Now has there been some change in fuel cells, are they going to be cost-effective compared to conventional large steam-generating plants, or is it just having them somewhere like downtown New York?

Mr. MARES. The fuel cell has the characteristic of being modular. It allows you to generate power in smaller increments than do the other facilities which I have just described to you.

Senator MELCHER. So it really doesn't compare, does it, to the other two processes?

Mr. MARES. Your question was what is available for central station power, and I was answering the question, and they are available for central station power.

Senator Melcher. I think my point is this, that where the cost of a kilowatt of electricity is relatively high it might be offset by the convenience of having them produce small amounts of electricity some place. They fit in, but they are not competitive on a cost effectiveness for say a 1,000-megawatt plant.

Mr. Mares. That may be so. I would rather go back and look at the analysis before I totally confirm it, but the expectation is that they will be used in the more modular fashion. It is not anticipated that there would be a single fuel cell stack that would be designed for a 1,000-megawatt plant.

It always was contemplated to be in modules of cells in stacks. One could contemplate over a period of time ultimately having 1,000 megawatts at a location, although one wouldn't put that configuration in initially. That is one of the beauties of the fuel cell technology, you don't pay a penalty for scaleup in that technology.

Senator Melcher. This committee perhaps loses track from one year to the next, but as for the incremental costs, it is my understanding that fuel cells, unless there is some brilliant breakthrough, would not be cost effective for any sizable plant.

Mr. Mares. If that were so, I would be very surprised because the private sector is putting a lot of its own money into that research and development.

Senator Melcher. What is the cost? If you are surprised you must have some cost per megawatt.

Mr. Mares. I will supply for the record the forecasted cost per megawatt for fuel cells.

[The information follows:]

Estimated Economics of Fuel Cells

Fuel cell economic estimates were developed by NASA/JPL with the cost of electricity calculated using the Electric Power Research Institute 1982 Technology Assessment Guide. A cost of 140 mills/kwhr was projected for near-term fuel cell power plants operating with natural gas. Projections for fuel cell power plants operating on coal were in the range of 70 to 80 mills/kwhr. Some developers predict that fully developed fuel cells operating on coal could produce electricity at considerably less than this. Potential economic opportunities exist particularly where the inherent advantages of fuel cells in cogeneration, siting, modularity and environmental compatibility could be fully exploited.

Senator Melcher. Now as to the first two, I am going to assume that the fuel cells really won't compare to say a 200-megawatt, 500-, 1,000-megawatt plant, central-based generating plant, but in the first two, what is the size of, what is being done right now in those two technologies?

Mr. Mares. As I recollect, the cool water project is a 100-megawatt electric project. The Grimethorpe, which is a pilot plant, is 28 megawatt electric.

Senator Melcher. Is it 20 watt electric or 20 watt thermal?

Mr. Mares. Curtiss-Wright is 13 megawatt electric. Twenty-eight megawatt electric is Grimethorpe, and the size of the proposed project involving the American Electric Power is 172 megawatt electric.

Senator Melcher. Are they ready to scale up or down?

Mr. Mares. Pardon me?

Senator Melcher. Are they ready to scale up to commercial size, or down?

Mr. MARES. Well, my recollection is that the project American Electric Power is considering would be intermediate in scale and might even be considered a first step toward commercial scale. It is certainly larger than the Grimethorpe and Curtiss-Wright projects.

Senator MELCHER. On these two areas, using coal for improved central-based generation of electricity, the R&D is the contribution from the Department of Energy is roughly less than $5 million in fiscal year 1983, and projected even less in fiscal year 1984?

Mr. MARES. That is correct.

Senator MELCHER. Now you mentioned EPRI. As I understand it, EPRI has been involved with grants for MHD and successfully demonstrated that at CDIF?

Mr. MARES. They have funded an inverter which is a device to convert DC to AC power. Tests have been conducted at the CDIF at Butte, but I forget the particular scale.

Senator MELCHER. Do you recall how much that cost?

Mr. MARES. No. I can supply it for the record.

[The information follows:]

COST OF TESTING THE EPRI INVERTER AT THE CDIF

The inverter for the CDIF was designed and constructed by Westinghouse under an EPRI contract at a cost of about $1 million.

The cost of installing the inverter at the CDIF, which was borne by the CDIF with DOE funding, was about $1 million and the inverter building, itself, cost about $1 million to construct.

Testing of the inverter at the CDIF took place over approximately a one-month period in conjunction with other MHD generator test objectives. The operating costs for the CDIF during this period are estimated at about $60,000.

EPRI and Westinghouse personnel at the CDIF participated in both the testing and evaluation of the inverter at an estimated cost of about $40,000. The EPRI inverter will remain at the CDIF and continue to be utilized in the ongoing test activities.

Senator MELCHER. Would it be fair to say that it might cost approximately what the Department of Energy is expending in fiscal year 1984 for the project that you mentioned that you are spending some money on.

Mr. MARES. Unless I knew what it costs, it is not appropriate for me to say whether it is fair or not fair, sir.

Senator MELCHER. It wouldn't be much off since we are only talking about $3 million.

Mr. MARES. Is that the number?

Senator MELCHER. No. You are talking about $3 million for expenditures, out of R&D funds for central-based generation capability in the one process that you mentioned. It relates to central-base generation of power.

Mr. MARES. Correct.

Senator MELCHER. So there is really a question of philosophy whether this is an area where Government ought to spend some money on MHD and central-based generation of electricity?

Mr. MARES. We are spending money on the research to support the technologies that could be used at central station.

Senator MELCHER. Three million bucks.

Mr. MARES. Well, that's for the fuel cells technology.

Senator MELCHER. Three million bucks just in the one?

Mr. MARES. That is correct.

Senator **Melcher**. I am going to leave fuel cells out unless you can demonstrate to this committee that somehow they relate to central-based generation of power at a size exceeding 200 megawatts. You know, it isn't like this Department was born yesterday. They have got some plans down there from a couple of years back as to where we are going with fuel cells, and really if things have changed, if that relates to central-based generation of electricity of a 200-megawatt size or greater, then I would like to know about it.

Mr. **Mares**. I will make some inquiries regarding that. My understanding is it can be used for central station electricity.

[The information follows:]

APPLICATION OF FUEL CELLS IN CENTRAL POWER STATIONS OF 1200 KW OR GREATER

First generation phosphoric acid electric utility fuel cell power plants are expected to be dispersed generators sited in the proximity of load centers. These will be gas or naphtha fueled. Some may be integrated with coal gasifiers to provide cogeneration steam and electricity. Early applications may be for cycling or peaking duty. Power levels are expected to be on the order of 10–50KW. Advanced fuel cell power plants (molten carbonate or solid oxide fuel cell systems) may include natural gas and coal fueled (i.e., gasified coal) base load plants providing electricity, or cogenerated electricity and thermal energy. Power levels could be up to several hundred megawatts. Because these systems will be large in size compared to early phosphoric acid systems it is anticipated that they will be used as central station power plants or would provide for incremental load growth in existing baseload plants. Advanced fuel cells are also expected to be applicable to smaller industrial and on-site applications as well as load following utility power generation.

Senator **Melcher**. Let's assume that it could be. We are going to spend $12 million on both?

Mr. **Mares**. That's about right.

Senator **Melcher**. So isn't this really a question of philosophy whether Government ought to be spending many dollars for R&D to improve central-based generation of power using coal?

Mr. **Mares**. Well, the judgment is what type of research dollars or what type of activity is appropriate for the Federal Government to spend, and then as it relates to MHD——

Senator **Melcher**. Exactly. How many dollars?

Mr. **Mares**. One of the issues is how much and what is the funding forecasted to develop the MHD technology until it could be adapted. When one evaluates that, it is a pretty healthy number.

Senator **Melcher**. Pardon me?

Mr. **Mares**. I say when one tries to estimate how much the technology base cost would be for the Federal Government for the number of years required before a retrofit would be possible for a project or an integrated project, and then the expected cost of that, we are talking about $500 million, and that's a large amount of money.

Senator **Melcher**. Well, you wouldn't want to—it is a large amount of money certainly now, but are you projecting that over what, 6 years, 10 years, 12 years?

Mr. **Mares**. 1991.

Senator **Melcher**. That's good. That's 8 years.

Mr. **Mares**. One has to ask oneself if working in that vein is the most useful way to use those dollars.

Senator **Melcher**. Well, in a budget of $138 million, it would take 30 percent I suppose or 35 percent of those budget dollars. In a budget of $312 million which is the amount appropriated for this fiscal year, dividing that up over 8 or 9 years it would take about 20 percent of that, but the point is that we are talking about your little part of a budget of what, for R&D—we will just keep it to R&D—possibly $1.1 billion?

Mr. MARES. Within the Department of Energy?

Senator MELCHER. Yes; for R&D.

Mr. MARES. Probably closer to $3 billion than $1.1 billion; energy research is about $1.6 billion, and when we add in fossil conservation, renewable and others, we are, I think it is the order of $3 billion.

Senator MELCHER. Let's keep it in R&D getting ready for commercial use.

Mr. MARES. My view, and I think I am accurately reflecting the administration's view, is when you are getting ready for commercial use, that is not where we can make the most effective use of our money.

Senator MELCHER. I didn't understand you.

Mr. MARES. If it is ready for commercial use, the private sector is the——

Senator MELCHER. That's exactly what I mean. Getting ready for commercial use, let's keep it in that.

Mr. MARES. Within the context of research, the Department is spending about $3 billion or requesting about $3 billion.

Senator MELCHER. All right. Let's narrow it down to electrical then. Would you say about $1 billion of that is getting ready for commercial use for generation of electricity, R&D for that purpose?

Mr. MARES. I think there is probably, and I would have to go back and look, on the order of $1 billion—that would be arguable—over $1 billion. That is because it would include fission. It would include fusion. It would include a significant part of fossil research. Most of the coal budget within fossil energy is decided ultimately to use coal to generate electricity.

Senator MELCHER. And that is a very small part of that billion dollars.

Mr. MARES. Well, whether it is a large or small part of a billion, it is a lot of money; $138 million is a lot of money, and we are concentrating on the technology base to enhance the utilization of coal in an environmentally and an economically effective way.

Senator MELCHER. Well, we won't get into how much, how top-heavy that budget is for nuclear, except just to point out that about half of it is for nuclear, maybe a little bit more than that—three-fourths?

Mr. MARES. Of the central station power, probably about half, if you treat fusion differently than nuclear.

Senator MELCHER. All right, if you want to treat it differently; we will just take Clinch River, light water reactors, and say about half of that?

Mr. MARES. That is about $600 million for the breeder program.

Senator MELCHER. Percentagewise we keep coming down. For the MHD program percentagewise we come down quite a bit.

Mr. MARES. Absolutely.

Senator MELCHER. So let me ask you this. Have you ever reviewed this paper, I guess it is called a white paper, prepared by the MHD Industrial Corps here in Washington in February of this year?

Mr. **Mares**. I believe I have. There was testimony last week or the week before, before a House Science and Technology Committee that I believe had that paper attached thereto.

Senator **Melcher**. Mr. Chairman, this is a paper, it looks like about 60 pages, double spaced. I would like to ask permission to have it made part of this record.

Senator **Warner**. Permission granted.

[The paper follows:]

A Strategy for the Early Commercial Development of MHD for the Generation of Electric Power

February 1983

Prepared Under the Direction of
THE MHD INDUSTRIAL FORUM
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PREFACE

The MHD Industrial Forum has reviewed the current MHD development program and recommends a strategy intended to place a prototype plant into operation on a shorter schedule and at a reduced cost. The strategy centers around a "retrofit" or the addition of a MHD unit to an existing power plant. The initial retrofit may not actually be commercially viable but would provide the basis for commercial viability in the shortest practical time span through a consortium effort involving utilties, industry and the government.

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INTRODUCTION

Magnetohydrodynamics (MHD) is an advanced power generation concept that can produce electricity using significantly less fuel than present fossil power plants, while also significantly reducing the quantity of pollutants discharged to the environment.

In this concept, coal is burned at a high temperature. A small quantity of potassium is added which makes the resulting combustion gas electrically conductive. This gas is passed through a MHD channel surrounded by a strong magnetic field, resulting in the production of electric power. The gas which leaves the MHD channel is still very hot, and is used to generate steam to drive a conventional steam turbine-generator for the further production of electric power.

Using current technology, this MHD plant would have an overall thermal efficiency of about 40-50% as compared to about 32-34% for a conventional steam plant and will require only about 75% of the fuel required by a conventional plant. There is the long-term potential for increasing the thermal efficiency of a MHD plant to the 50-60% range, which could reduce fuel requirements to a little more than half that of a conventional plant.

The MHD concept has an additional bonus in that the potassium, added for electrical conductivity, combines with the sulfur in the coal to form potassium sulfate which becomes a solid and can be removed with the coal ash prior to discharging the flue gas to the environment. A 95% or greater sulfur collection efficiency is expected which equals or exceeds the best SO_2 removal efficiency using current scrubber technology for conventional plants. When combined with the lower sulfur input (less fuel used), a MHD plant can greatly reduce the amount of sulfur compounds discharged to the environment.

The development of the components for a MHD plant has reached the point where it is desirable to construct a small commercial size plant which will provide the information and basis for further development of MHD.

Since a MHD plant includes a conventional steam turbine, one concept that appears attractive is a "retrofit" or the addition of a MHD unit to an existing power plant. The retrofit MHD plant would utilize the existing turbine-generator, cooling system, and be at an operating site for which most support functions and personnel are already present.

In addition to being significantly less costly than a completely new plant, the retrofit will result in a greater than 50% increase in power generation capability since the existing steam turbine-generator will remain the same.

The commercial development of MHD has the potential for increasing electrical generating capability, replacing oil with coal utilized at a high efficiency, and reducing adverse impact on the environment.

LONG TERM GOALS

1. Establish MHD as a competitive means of electric power generation at the earliest possible date.

2. Develop confidence in MHD by electric utilities at the earliest possible date.

3. Operate first prototype plant, as a retrofit to an existing utility unit, by 1991.

4. Operate several commercial MHD plants by the year 2000.

5. Maximize economy, efficiency, availability and reliability of MHD for future plants, and minimize environmental impact.

SHORT TERM GOALS

1. Modify the present MHD program to support a retrofit. In addition to those areas listed below (Items a-h), the program will lead to the design, installation, and operation of a MHD retrofit for utility service by 1991.

    a. Scale-up combustor development which leads to 300 MW_t unit.

    b. Continue channel development for a unit of 50-70 MW_e (approximately 300 MW thermal) with a minimum continuous operating life of 2000 hours.

    c. Continue development of power conditioning equipment.

    d. Continue development of MHD diagnostic instrumentation.

    e. Continue development of heat recovery seed recovery (HRSR) systems. Demonstrate 90% seed recovery.

    f. Demonstrate seed recovery and reprocessing in first retrofit unit.

    g. Demonstrate that the combined steam/MHD plant effluent meets or exceeds all environmental requirements.

    h. Demonstrate that MHD is economically and commercially viable for utility use.

2. Continue MHD research and development to improve efficiency, reliability, and to reduce cost.

NEEDS OF ELECTRIC UTILITIES

Magnetohydrodynamic power generation has been considered a promising alternative for the more effective use of fossil fuel for some years. A few years ago, it became clear to some of the electric utilities that the technology had advanced far enough that some specific application should be made. In 1980, the utility group met to start work on the technology application effort. There are three main thrusts that have been identified:

1. The direct application of spin offs from MHD technology to existing power plants,

2. The retrofitting of existing plants with MHD generators, and

3. The continued progress toward an advanced MHD power station.

Although all of these areas are desirable and promising the development of an MHD generator based on the data obtained from the present program was deemed most important.

The application of technology developed in the MHD program to existing power plants is being directly supported by the individual utilities. Combustion technology developed from the MHD program has led to the design of burners that may soon allow the conversion of oil burning equipment to coal. This can be done at minimum environmental impact and at appreciable savings in the price of electricity. The emission reduction control techniques developed can also be applied to other combustion systems and will reduce particulates, NO_x, and SO_x emissions. Slagging information generated by the MHD program can be applied to ordinary coal-fired boilers, increasing their output and reliability while at the same time reducing the backup oil and gas requirements. Improvement in combustion also increases the quantity of electricity gained from the fuel. Diagnostic instrumentation and controls developed in the MHD program are important in the utility programs to extend plant life and reliability.

The important thrust of this program is seen by the utilities group as being the retrofit of existing power plants. Oil-fired and coal-fired plants are both candidates. Several utilities have developed retrofit designs, and the utility MHD Users Group is working with Mountain States Energy Inc. on the identification of power plants that could be candidates for retrofit. At the same time, the Users Group is working with the Pittsburgh Energy Technology Laboratory to design the components of the Federal programs necessary for the first retrofit plant. The interest in such a retrofit is because of the improved efficiency, reduced site problems, oil replacement, the promise of acceptable environmental impact, and reduced capital demand. A retrofit would meet many requirements even though it did not meet the ultimate potential of a final system.

The long-term future does demand a continuing research and development program, but success of the retrofit would provide an industrial base from which additional improvements can be derived. These improvements coupled with basic research and development is the approach most likely to lead to the most efficient fossil fuel power plant at the least development cost.

DEVELOPMENT PLAN

General

As a retrofit appears to be the most practical method for demonstrating the commercial viability of MHD, it is recommended that a retrofit be considered as the next phase of the MHD development program. A retrofit has significant advantages as compared to a completely new plant. The major advantages being:

- Commercialization of MHD at the earliest date (early 90's)
- Minimum development costs
- Extensive involvement by the user (electric utilities) in MHD development
- Near term commercial market broadened to include the conversion of oil-fired units to coal via a retrofit

This document describes one of several possible engineering plans to accomplish a retrofit. Specific design parameters will be decided when the generating unit to be retrofitted is selected, and will be the result of mutual agreement between the manufacturers and the host utility.

The size or capacity level of a retrofit is also important and determined by several factors. The more important of these are initial capital costs, scale-up risks and the incentive for operating the MHD unit on a commercial basis after the test objectives have been met. Consideration of these factors has resulted in proposing an MHD power train of 50 MWe (nominal) output capacity from the MHD generator for the retrofit program.

This corresponds to a thermal input of about 350 MW to the MHD coal combustor. The coal will be burned with preheated oxygen enriched combustion air. The oxygen required is supplied from an oxygen plant (air separation unit) which becomes part of the facility equipment. The retrofit will have a heat recovery and seed recovery (HRSR) system. This HRSR system will either replace or operate in parallel with the existing steam generator (boiler). With the later arrangement, the existing plant will not suffer any capacity loss when the MHD power system is not operating. Conversely, the plant will benefit from an increase in power output when the MHD power system is operating. The HRSR system will also provide steam for the turbine driven compressors which are required in the manufacturing of oxygen and the compression of enriched combustion air to the operating pressure of the MHD coal combustor.

As discussed below, very signficant progress has been made in the development of subsystems and components in the MHD technology development program. Now is the time to plan for a retrofit program to demonstrate the commercial viability of MHD.

Channel

Results from channel lifetime testing have been very encouraging. A 1000-hour electrode test was conducted under simulated coal-fired commercial power plant operating conditions a year ago. Further testing since then has extended the total accumulated operating time on the same electrodes to 1300 hours. This long duration testing has demonstrated that channel lifetimes beween 5000 and 8000 hours can be projected in early commercial operating units.

Since the tested electrodes showed little wear after 1300 hours, we are quite confident that our retrofit goal of 2000 hours of continuous operation between overhauls can be achieved.

MHD channel long duration performance testing at 20 MW and 50 MW thermal levels is planned both with simulated coal firing conditions (oil + ash) and with direct coal firing. The objective of this channel testing is to extend channel lifetime and to provide additional channel design information.

Short duration channel testing at a relatively high power level of 300 MW is proposed as a continuation of the ongoing high power channel performance testing. It is expected that this performance testing basically will have reached its design objective within a year. This will provide performance verification of the MHD generator at essentially the same enthalpy extraction as that required for the retrofit.

Since the channel is the central item of an MHD power system, continuous channel development is a natural and important part for advancement of MHD technology.

The channel for the proposed retrofit is expected to be of the supersonic mode (as opposed to subsonic). This operating condition offers the advantage of being the design for which most technical experimental and operating data is available and it is the design with the lowest initial capital cost.

Combustor

Experimental work with MHD coal combustors has so far been limited but substantial progress has been reported recently. A coal combustor has been tested with 20 MW input, and a two-stage slagging combustor of this scale has been tested in integrated operation of a coal-fired MHD power train with promising results.

A most important part of this continuing program development phase is the successful testing of a coal combustor of 50 MW thermal level. It will provide combustor performance and scaling information which are considered vital for the retrofit. After acceptable combustor performance has been demonstrated at the 50 MW thermal level in separate combustor testing, it is proposed to operate the combustor as part of an integrated coal-fired MHD power train at the same power level.

The operating conditions for the proposed retrofit will be about 4 - 4.5 atmospheres pressure, 2800° K temperature and have a slag removal of at least 60%. Since all of these parameters have been essentially achieved during testing of the small (20 MW) unit, we are confident that a larger combustor (350 MW) can be developed in time for the retrofit program to be carried out with a reasonable level of confidence. The development program will also minimize combustor heat losses which will improve the overall cycle efficiency. The combustor will be cooled by a high pressure boiler feedwater. An air/fuel equivalence ratio of 0.9 is planned for NO_x emmission control.

Magnet

The magnet system consists of three major items: the field coil/dewar assembly, the refrigeration system, and the power supply and controls. With the exception of the field coil and dewar assembly, all of the components of the magnetic system are currently standard commercial items. As the design and fabrication techniques for large superconducting coils have been available for over a decade, the coil requirements for a retrofit appear to be a reasonably straight forward extrapolation of existing magnet technology.

Detailed studies have shown that for a supersonic channel, superconducting magnets with a magnetic field strength of 4.5 Tesla (in lieu of 6 Tesla) can be used which significantly reduces the magnet cost and risk. Once MHD technology is accepted, 6 Tesla fields can be used to further improve plant performance.

A large (180 ton) superconducting magnet producing a peak field of 6.2 Tesla has already been built and successfully tested. This is substantially larger than the 4.5 Tesla magnetic field proposed for the retrofit.

HRSR System

Continued experimental and analytical development work related to heat and seed recovery from the MHD generator exhaust gas and pollution control of the effluent gas is proposed to provide further design information in these important areas. This includes the behavior of ash and seed throughout the system including materials corrosion and seed recovery and seed regeneration, as well as information of the gas chemistry for control of SO_x, NO_x and particulates. All of this will provide information for the design and operation of the HRSR System for the retrofit.

The actual design conditions of the HRSR system will be selected to match the steam pressure and temperature requirements of the existing power station in which the retrofit will be implemented.

Diagnostic

The development of new and advanced diagnostic techniques is desirable to measure the characteristic parameters necessary to the successful scale-up of MHD components. Significant achievements have been made with microprocessor-controlled equipment, however, state-of-the-art instrumentation does not currently have the measurement capability at the actual process conditions. Continued diagnostic instrumentation development will lead to the analysis of the entire energy process of the combined MHD/HRSR cycle.

On-line techniques (which would be available through a retrofit) offer the best means to characterize the MHD combustion process such that basic data can be obtained for modeling and scale-up of the process. Many of the devices being developed for the MHD program have the capability of being applied to conventional power plants; which could lead to improvements in both efficiency and environmental emmissions.

Seed Reprocessing

In an open cycle MHD system, potassium compounds (seed) are injected into the combustion gas stream both to increase electrical conductivity required for the MHD channel gases (plasma) and to remove sulfur dioxide (SO_2) formed by oxidation of the sulfur in the fuel. Sulfur-free potassium compounds will remove SO_2 by forming potassium sulfate (K_2SO_4) which can be recovered as a solid from the combustion gases. A sulfur-free potassium compound must be regenerated from the recovered K_2SO_4 and recycled in order for the process to be economically attractive. The formate process has been selected as one of the more promising methods for this purpose. The formate process was developed in Germany in the 1930's for converting locally mined K_2SO_4 to potassium carbonate (K_2CO_3). The process was actually used industrially until the mid 1940's. Unfortunately, nearly all of the actual operating data was lost as a result of World War II. We are however, quite confident that during a pilot plant evaluation of the formate process, all of the operating parameters could be redetermined. This pilot plant program would be quite inexpensive and could be conducted in a relatively short time span.

Several studies have shown that the formate process is theoretically sound, and technically attractive. Energy requirements are relatively low and capital costs are favorable. Commercial equipment is currently available for the individual components of the process, but as stated above, pilot plant test data is required prior to implementing a final design.

While reprocessing appears necessary for full scale commercial MHD development, recent studies indicate that there may be a commercial market for the modest quantities of potassium sulfate resulting from the proposed retrofit. Consequently, the seed reprocessing system could possibly be delayed until after successful operation of the prototype plant. Once a retrofit site has been selected, a study will be conducted to determine whether or not the seed reprocessing system should be delayed. Regardless of the results of this study, the overall MHD schedule will not be adversely effected.

MHD RETROFIT - NOMINAL DESIGN PARAMETERS

Gross Power Output (MW):	
MHD	50
Steam Turbine	70-80
Total	120-130
Estimated Plant Auxiliary Power and Losses (MW)	10
Net Total Power Output (MW)	110-120
MHD CHANNEL:	
Operating Mode	Supersonic
Continuous Operation Between Overhauls (hours)	2000 Minimum
Thermal Input (MW)	300
COMBUSTOR:	
Fuel	Pulverized Coal
Thermal Input (MW)	325-350
Operating Pressure (ATM)	4 - 4.5
Operating Temperature (°K)	2800
Design Slag Removal (%)	60 Minimum
MAGNET:	
Maximum Field (Tesla)	4.5
HRSR	Demonstrate 90% Seed Recovery Satisfy NO_x Emission Requirements
Sulfur Removal and Seed Reprocessing	Satisfy SO_x Emission Requirements Demonstrate Formate Process For Seed Reprocessing

MHD RETROFIT SCOPE

A retrofit is essentially the addition of a MHD generator to an existing power plant. The MHD system burns coal using high pressure air which has more than the normal amount of oxygen to produce a very high temperature (4500°F) gas. This gas is passed through a MHD channel surrounded by a superconducting magnet generating electricity. The hot gas exiting from the channel goes to a boiler in which steam is generated to drive the conventional steam turbine. The potassium formate added in the combustor to make the high temperature gas conductive, decomposes and the potassium combines with any sulfur in the fuel to form potassium sulfate. The sulfate is collected and reprocessed to formate for recycling. By this means, almost all the sulfur in the fuel is captured with a discharge to the environment significantly less than a conventional coal-fired power plant.

The intent of a retrofit is to retain as much of the existing plant as practical. If the retrofit is to a plant that has been retired, it will be desirable to remove the existing boiler. If the retrofit is to a plant which is still considered in service, then it will be desirable to retain the existing boiler and cross connect the steam and feedwater lines so that the turbine may continue to operate if the MHD retrofit is unavailable.

The scope of a retrofit is as follows:

- Add MHD Combustor, Channel, Magnet and Electrical Assessories
- Add HRSR to replace or in parallel with the existing boiler
- Add air compressors, drives and heat rejection
- Add Air Separation Unit
- Add Seed Reprocessing System
- If necessary, add coal receiving and handling
- Add sludge disposal and if necessary, ash disposal
- Provide diagnostic instrumentation to determine MHD performance

MHD RETROFIT SCHEDULE

The schedule assumes an ongoing MHD program funded at a level sufficient to obtain design criteria for the retrofit components and to confirm the component design.

The schedule recognizes the need to establish the retrofit consortium, identify the host utility and the retrofit site, and obtain firm financial commitments for the entire project prior to the planned commitment of any major cost. One to two years, 1983 and 1984, are allowed to identify the site and obtain financial commitments. During this time, cash flow would be minimized.

The schedule indicates that detailed engineering would start early in 1985 followed by the procurement of major components. Site construction would start in 1986. Since the retrofit is the first of a kind, four (4) years are allowed for construction which is significantly longer than would be expected for a conventional plant of about the same size.

The MHD flow train would be ready for test operation, without the HRSR, in early 1988. This will allow most of 1988 and 1989 for modifications that may be necessary prior to retrofit initial operation in late 1989.

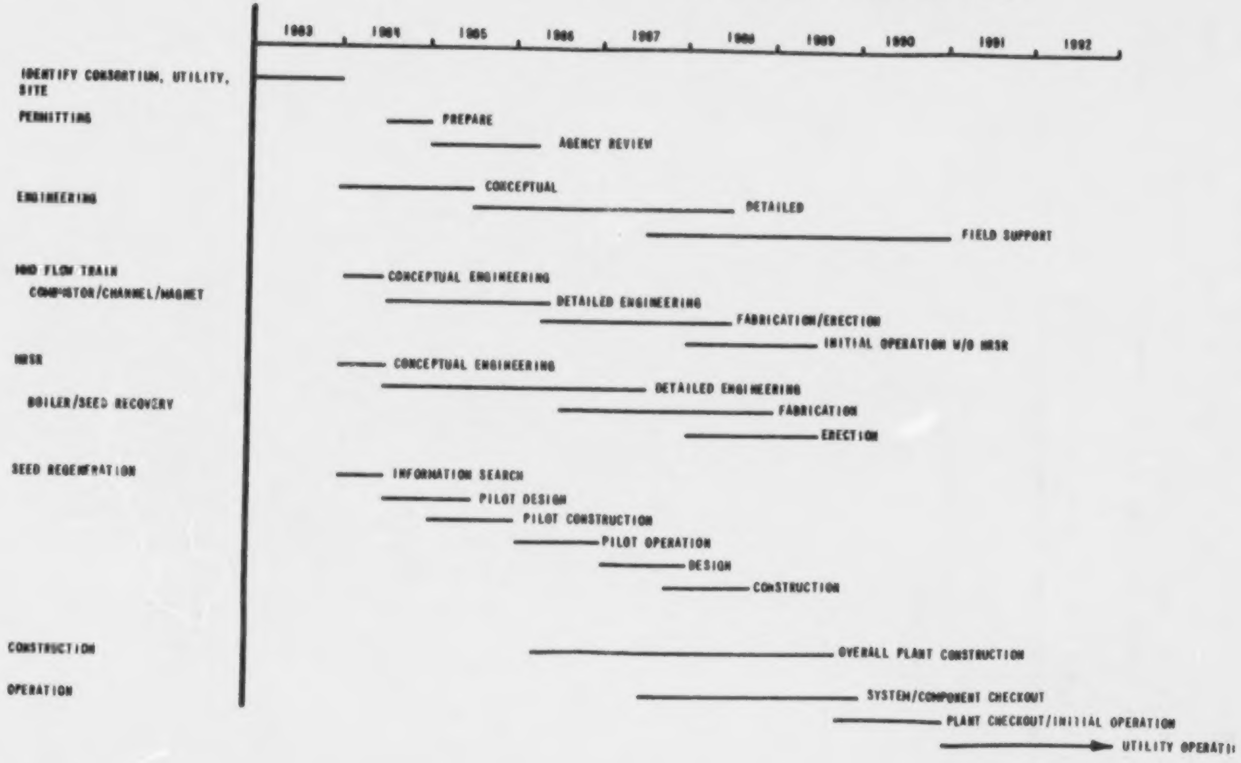
The HRSR represents a major original engineering effort and as shown, probably represents the critical path. The HRSR will not be available for checkout until the middle of 1989. To allow adequate time for HRSR modifications, the plant checkout and initial operations is shown from the middle of 1989 into late 1990.

The seed regeneration system is based on a commercial process used during the 1930's for which the engineering details appear to have been lost. Therefore, it is necessary to obtain pilot plant operating information to re-establish these lost details.

While the completion of the seed regeneration portion of the plant is not expected prior to early 1989, it is anticipated to proceed on an orderly manner. In any event, seed regeneration would not become critical until commercial operation in late 1990.

Initial operation of the retrofit would start in late 1989 with expected commercial operation by the end of 1990.

MHD RETROFIT SCHEDULE



MHD RETROFIT COST

The MHD retrofit estimate is intended to identify those costs directly associated with the construction of the retrofit and is based upon the nominal design parameters listed herein. The actual cost would vary depending upon the final site selection and size of the retrofit. For the estimate to be viable, an ongoing MHD development program is necessary to establish and confirm many of the parameters for the design of retrofit components.

The estimate covers the cost of components which will be fabricated at a commercial size for the first time and therefore, the costs can not be compared to the many studies which consider a number of plants of given size. It is reasonable to assume that future retrofits of about the same size could be completed at a significantly lower cost.

The estimate includes $25,000,000 for coal/ash handling which is appropriate for a retrofit to an oil site. A significant portion of this cost can be omitted if the retrofit is on a site which has coal-fired units.

The seed regeneration cost includes the construction and operation of a pilot plant. If the process information search shown on the schedule for early 1984 is successful in recovering adequate information, it may be possible to delete the pilot program and the associated cost. While reprocessing appears necessary for full scale commercial MHD development, recent studies indicate that there may be a commercial market for the modest quantities of potassium sulfate resulting from the proposed retrofit. Consequently, the seed reprocessing system could possibly be delayed until after successful operation of the prototype plant and $18,000,000 can be initially deleted from the cost estimate.

Since the retrofit is the first of a kind, the contingency is established as 25 percent of the direct construction cost.

As indicated in the estimate, all costs are shown as 1983 costs.

COST ESTIMATE

This cost estimate assumes the support of an ongoing MHD development program and includes only the costs directly attributable to the retrofit. The components which are unique to MHD are assumed to be funded by the Government.

ITEM	Cost $ in Millions		
	Government	Private	
Structures and Improvements		10	
Coal/Ash/Seed Handling	5	20	
HRSR	64		
Compressors and Accessories		20	
Electrical and Controls		6	
MHD Flow Train	65		
Combustor/2 Channels			
Magnet System			
Inverters			
Air Separation Unit		20	
Seed Regeneration	18		
Subtotal	152	76	
TOTAL DIRECT COSTS			228
Indirect Construction Cost		25	
Professional Services		15	
Contingency at 25%	38	19	
Subtotal	190	135	
Total 1983 Project Cost Excluding Owners Costs			$325

FUNDING

General

The following pages indicate possible roles of various organizations in funding the MHD Development Program under discussion. Only further discussion with the parties involved can determine the specific funding sources.

The important factors are:

1. As MHD approaches commercialization, government funding would reduce measurably and private sources form the larger share.

2. Since electric utilities are the ultimate users, they would bear the majority of funding with government, manufacturers, EEI/EPRI and A/E's supporting project funding.

3. The Synfuels Corporation may be expected to become an important part of the funding of the retrofit.

Utilities

1. Host Utility - Provide:

   Existing fossil fired generating unit

   Land for new plant as well as construction area

   Test, start-up, and operating personnel

   Program management (Project Manager and staff)

Portion of capital cost measured by the value to the host utility of incrementally lower bus bar cost of electricity or increased capability.

2. Other Utilities - Provide:

Personnel for partial needs of MHD plant operation

Part of capital and start-up operating cost

Federal Government

Portion of supporting R&D for retrofit which is not supported by manufacturers, EEI/EPRI, state government, and foreign governments.

R&D for future improvements in MHD

Provide loan guarantees through the Synfuels Corporation

State Government

Labor of state employees for permitting and environmental monitoring

Cash grant

EEI/EPRI

R&D to support retrofit, e.g., power conditioning, seed recovery, combustor . . . .

Manufacturers

Provide equipment, material, and construction supervision at minimum or zero profit

Architect/Engineers

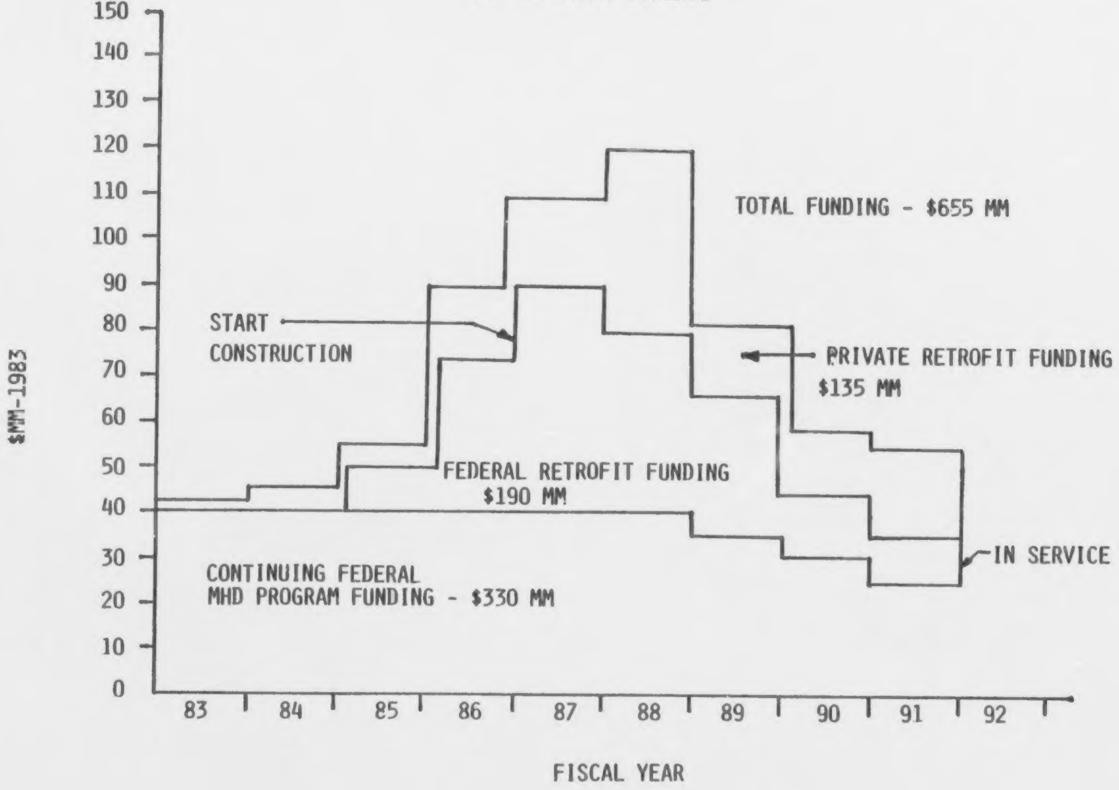
Provide A/E services at minimum or zero profit

Foreign

Provide cash grants and minor equipment for retrofit

Input to Federal Government long range R&D program

ESTIMATED
FUNDING FOR MHD DEVELOPMENT PROGRAM
1983-CONSTANT DOLLARS



ROLE OF PARTICIPANTS

General

The following pages indicate possible roles of various organizations in the MHD Development Program under discussion. Only further discussion with the parties involved can determine their roles in detail.

The important factors are:

1. As MHD approaches commercialization, government participation would reduce measurably and private participation form the larger share.

2. Since electric utilities are the ultimate users, they would lead the program with government, manufacturers, EEI/EPRI, and A/E's supporting the effort.

3. The Synfuels Corporation may be expected to become an important part of the organization.

Utilities

Lead role on retrofit - "Project Manager"

Advisors in supporting research

Key Advisors in design of retrofit to suit utility needs for MARCOE (Maintainability, Availability, Reliability, Constructibility, Operability, and Efficiency) as well as minimum first cost.

Advise utilities of progress and benefits of MHD to utility customers.

Federal Government

Supporting R&D for retrofit

R&D for long range improvement of heat rate, availability, reliability, and cost reduction

Interaction with foreign governments

Environmental variances if required

Tax relief for host utility for retrofit

Public relations for MHD

State Government

Participation highly dependent upon interest of state where retrofit is located.

Coordinate with Federal Government regarding environmental variance (if required).

Coordinate with Federal Government regarding tax relief for host utility for retrofit.

Public relations for MHD

EEI/EPRI

Power conditioning development and test

Other R&D to support retrofit, e.g., seed recovery

Serve to solicit utilities willing to contribute directly to financing the retrofit capital cost.

Manufacturers

Input to retrofit design

Furnish equipment, supervise installation and start-up, monitor performance of their equipment.

Architect/Engineers

Scheduling of project

Cost estimating

Conceptual plant design

Bid major equipment and construction

Detailed design

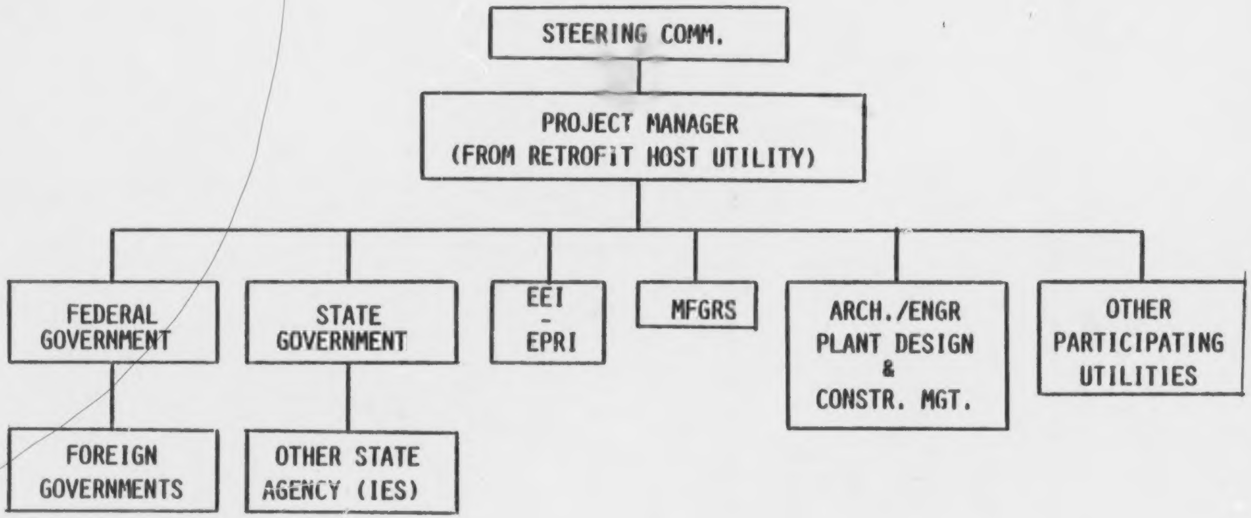
Manage construction and start-up

Foreign Government

Advisory on design of retrofit and future R&D

Participation in retrofit as negotiated

POSSIBLE
ORGANIZATION CHART
MHD RETROFIT PROJECT


STEERING COMM.
PROJECT MANAGER (FROM RETROFIT HOST UTILITY)
FEDERAL GOVERNMENT
STATE GOVERNMENT
EEI - EPRI
MFGRS
ARCH./ENGR PLANT DESIGN & CONSTR. MGT.
OTHER PARTICIPATING UTILITIES
FOREIGN GOVERNMENTS
OTHER STATE AGENCY (IES)

Senator **Melcher**. Now this paper says that effort and coordinated effort particularly with the Department of Energy, between private industry and the Congress and the Department of Energy could be better accomplished if there were a plan for bringing MHD on line perhaps in the commercial stage by the year, sometime in calendar year 1990 with initial operation for utility operation of the plant by sometime in 1992, so that is perhaps a little bit faster than your 1991. I don't know whether you are just talking about a demonstration plant in 1991.

Mr. **Mares**. I believe that plan proposes a retrofit test in an existing utility facility by 1991 and does not contemplate or expect the utility would proceed and put in a full-scale unit by 1991.

Senator **Melcher**. I believe it would be our plan to make sure that by that time we are at some point to know whether you can (a), retrofit successfully, and (b), based on its operation to know whether it is cost effective for private utilities to go ahead and retrofit other plants.

Mr. **Mares**. That is what, as I recollect, the aim of that plan is, but it also contemplates about $500 million of Federal funding during that timeframe.

Senator **Melcher**. Yes, $500 million; but I don't know how much you can rely on any particular set of figures.

Mr. **Mares**. That is just taking their numbers today without any forecast of what finally would actually happen. It is rare that a forecast turns out to be low.

Senator **Melcher**. I don't know. You just turned back some money that you said wasn't——

Mr. **Mares**. Not for that type of work.

Senator **Melcher**. Not for this type of work because you haven't been doing too much of it.

Mr. **Mares**. I said that type of work.

Senator **Melcher**. What was the R&D money that you are turning back? For R&D on noncommercial work?

Mr. **Mares**. These funds were for feasibility studies in the alternate fuel program that were concluded at a cost less than originally contemplated; and, the other portion was associated with the demonstration plant projects that did not go forward.

Senator **Melcher**. This MHD plant would have a lot shorter timeframe in terms of starting up and the completion of it, than for instance Clinch River, would it not?

How long have we been on Clinch River?

Mr. **Mares**. I think—I will defer to you, sir. You followed it longer than I do.

Senator **Melcher**. I can't even remember when we were not on Clinch River. That is going back 14 years.

Mr. **Mares**. Clinch River opens up a different resource to the Nation. MHD does not open up a new resource to the Nation, sir.

Senator **Melcher**. Well, isn't Clinch River to demonstrate that light water reactor nuclear plants, which don't look too cost effective right now, have led us to the point where maybe Clinch River with the breeder would be cost effective?

Mr. **Mares**. I think the judgment is that the breeder technology will enhance the economic resource base of this country to generate electricity, and as such it is a very important step for the Nation.

MHD does not open up a whole new basis for this country. We have several technologies that are designed to enhance the utilization of coal to make electricity that are going forward. We are supporting them. We are not neglecting this resource.

Senator **Melcher**. You are supporting in R&D one other approach, plus fuel cells.

Mr. **Mares**. Also, we are supporting gasification combined cycle by virtue of some of the base work we are doing related to gasification.

Senator **Melcher**. You are not spending any money on it.

Mr. **Mares**. Not at the same scale as cool water; we are putting research dollars into understanding gasification, in understanding gasifier systems, understanding the environmental aspects.

Senator **Melcher**. Yes; and all with the hope of proving that coal can be utilized in a more cost-effective and environmentally benign way which affects the cost effectiveness.

Mr. **Mares**. Yes.

Senator **Melcher**. So this is along the same line. Now do you find any, well, I guess you haven't really looked, but you mentioned that it would be $550 million between now and the end of fiscal year 1991 or in fiscal year 1992 more accurately, which is about 9 fiscal years, 9 or 10 fiscal years. So it would be somewhere between $55 and $60 million that would be the Federal expenditure, but of that are you aware that $190 million would be for synfuels? I do not mean Synfuels Corporation funds that are appropriated.

Mr. **Mares**. My understanding is that there is an opportunity for any group that wants to, to make application to the Synthetic Fuels Corporation to fund a first commercial-scale plant in MHD. I don't know if that has been done to date, and it would then be up to the corporation to evaluate that particular proposal.

I did not recollect in their proposal that they were going to receive funds from the Synthetic Fuels Corporation.

Senator **Melcher**. I am sure one of these documents is available for you if you haven't got it, but of that $550 million total, $190 million of it would come from an application to the Synfuels Corporation for Federal retrofit funding.

Mr. **Mares**. If it is a demonstration project that is designed to perform process development activity, then it may not—and you are better advised to speak to the Synthetic Fuels Corporation than me, but my understanding is that they would not be inclined to support, in effect, a large pilot plant.

They are trying to support first commercial ventures.

Senator **Melcher**. That is exactly what this is—first commercial venture, an attempt to be a first commercial venture. The Federal funding fits in with some of the points you have already made that you are seeking, combustion efforts to find better ways to combust coal to produce electricity that is for a central-based generating station, in a more environmentally sound way.

Of course, that is one of the primary goals of MHD. The chart that they project shows Federal funding constant in R&D work, including this fiscal year, which is already appropriated, by the way, so we can deduct that off of the $520 million projected through fiscal year 1984 into fiscal year 1992, and so we are talking about perhaps an outlay of R&D work paid for by Federal Government of something around $300 million during the course of that time; $190 million would be by application to the Synfuels Corporation, and the top figures up here the private companies would put up through EPRI or through this forum, MHD industrial forum.

Mr. **Mares**. The sum of $300 million over a 9-year period is a lot of money. We have talked a little bit about ERAB here earlier and I would like to read a paragraph from one of their reports from November 1981.

> There are other technologies such as combined cycle gas turbines available for increasing the efficiency of large central power generation stations that do not have the extreme temperature erosion problems associated with the use of coal and MHD. For this reason, the Board foresees little commercial demand for this technology, and therefore concurs with the planned phaseout of this program.

Senator **Melcher**. Who is that?

Mr. **Mares**. That is the Energy Research Advisory Board, November 1981.

Senator **Melcher**. That is the Department of Energy group that you weren't sure was a part of the Department of Energy?

Mr. **Mares**. As we have defined it, it is our group, as defined in the course of the hearing today.

Senator **Melcher**. Dr. Mares, it would seem to me that this Advisory Board appointed by the Department of Energy would either concur in the Department of Energy's budget or would make a case where that budget was wrong and be replaced either by the Department of Energy or by the President, so I wouldn't be suprised to find that Advisory Board concurring in the Department's budget, which is after all the President's budget, and finding justification for whatever that budget is.

Mr. **Mares**. Well, the Board is quite independent and has taken positions different from the administration on several research issues, but I would suggest that——

Senator **Melcher**. I guess that is true. They gave a pretty low rating to Clinch River but they didn't say phase it out. They just said get some commercial dollars in it from the private sector.

We always thought that. There has been about as much money—no, not now, not as of the last couple of years, but about 50 percent of the dollars that have been spent on R&D work in MHD technologies have been spent by private industry. Now we are trying to find——

Mr. **Mares**. I am not sure that is correct, Senator. I am not sure within the past 10 years that is correct.

Senator **Melcher**. I am talking about the whole time, and the last 10 years would be the key years, but you know there are project models sitting around in private industry that have been there for years and have been shut down because there isn't any leadership from the Federal Government.

Mr. **Mares**. I think it is more a fact of the judgment of private dollars as to how to be intelligently spent.

Senator **Melcher**. I don't think that is true at all, Dr. Mares.

Mr. **Mares**. There was a lot of private sector funding spent in the early days particularly by AVCO trying to develop this concept in the forties, fifties.

Senator **Melcher**. I think a little bit of research into what AVCO thinks and what Westinghouse thinks, what GE thinks and what Reynolds Aluminum thinks and what MIT thinks, would show you that there has been plenty of dollars spent by the private sector on MHD research.

Senator **Warner**. Senator, we want to try——

Senator **Melcher**. I am just about concluded. I just encourage you to do that, Doctor.

Mr. **Mares**. I will look at it again, sir.

Senator **Melcher**. And finally, Doctor, in order to make sure that there is some resolution of this reluctance by the Department of Energy to recognize and even keep abreast of what the MHD research community, the private sector, the universities and other research centers capable of funding MHD research are doing, I think perhaps it is time to introduce authorizing legislation to incorporate the planning of this private sector group with congressional plans and with those of the Department of Energy and the administration.

Then we wouldn't have to—you would come up with a game plan in MHD and you would come up here and be talking to us about what the possibilities are and not trying to demonstrate to us it is unnecessary for the Federal Government to continue its part. I think you are at a disadvantage in this program because simply there is no real proposal directing the outcome, and I think perhaps authorizing legislation should be considered by this Congress to incorporate a game plan and make some headway. I will be introducing a bill to that effect and we will be discussing it further with you to get your reaction.

Mr. **Mares**. I will be happy to consider that. I am happy to talk to the group at any time. I don't think, based upon the national experience to date, that since the Government wouldn't be the user of the technology that we are the best institution to decide what the plan of its development ought to be.

Senator **Melcher**. You are not going to be the user of breeder reactor electricity either, except to buy it.

Senator **Warner**. Thank you, Senator. One wrap-up question on coal—what about this sludge situation, cleaning up the flue gases? Have you got any proposal or process of disposal of this?

Mr. **Mares**. We are doing some work in fiscal year 1983 concerning the characterization of the sludge from the flue gas cleanup, and we expect that work will be concluded and that we will have met the need for waste characterization.

Senator **Warner**. Well, all right; well, thank you, Mr. Secretary. We will have other questions for the record. We appreciate your appearance today.

We will now hear from Mr. William Willis, General Manager, TVA.

Mr. Willis, we thank you for joining us today. You are addressing a very interesting new development of technology—fluidized bed combustion, and the subject has been of great interest to Senator Ford of Kentucky, so Senator, do you have any opening comments?

Senator Ford. Mr. Chairman, I thank you for the opportunity. As you know, Mr. Willis is bringing out in his statement the atmospheric fluidized bed combustion proposal that we have going is something that we believe is on the verge of being commercial. A powerplant can be retrofitted by building a new boiler. We have had a 20 megawatt pilot project that has been running approximately 2,000 hours, used almost what, 10,000 tons of coal.

We just think it is on the verge of being something of importance to the Congress, and I have introduced legislation that would make this project doable. It is about one-fourth or 25 percent of the outside funds maximum will be put up by the Federal Government only to assure its completion. I am very pleased that Mr. Willis will be here today to bring the testimony about this project on what they have been doing, and I welcome him here, Mr. Chairman.

Senator Warner. Yes. Proceed, Mr. Willis.

Mr. Willis. Thank you, Mr. Chairman. Thank you, Senator Ford. We are very happy to be here today.

Senator Warner. We will put your whole statement in if you want to go to the crux of the matter.

Mr. Willis. All right. Thank you, sir.

STATEMENT OF WILLIAM F. WILLIS, GENERAL MANAGER, TENNESSEE VALLEY AUTHORITY

Mr. Willis. I am William F. Willis, General Manager, Tennessee Valley Authority, and I appreciate this opportunity to describe and discuss TVA's fossil energy research and development program, and in particular the development of atmospheric fluidized bed combustion technology.

We appreciate the interest shown by Senator Ford and other members of this committee for the national fossil R&D effort in general, and in particular for the AFBC technology development.

TVA's R&D program is intended to provide technologies, techniques, and procedures which reduce the operating costs of the power system. This will come through increases in the power system reliability, reductions in capital investment, efficient end use of electricity, and development of electric generating options for future new and replacement capability.

An attempt is made to balance TVA's program by relying strongly on the independent R&D carried out by the Electric Power Research Institute, EPRI, conducting joint efforts with EPRI and other agencies and carrying out the internal B&D required to solve system or site-specific problems.

Because TVA is one of the Nation's largest coal-burning electric utility systems, it has several active projects in the fossil energy area which include experiments in developing rapid measurements of coal quality, economical methods for reducing biofouling in biofouling condensers, and improvements in power plant waste handling, utilization, and disposal. One of TVA's largest efforts, however, has been in the development of AFBC to generate steam for electricity production.

This technology offers the utility industry an opportunity to utilize the abundant and less costly coals which are not being used in conventional power plants due to environmental standards. Because of the capture of the sulfur is inherent during the combustion process, the opportunity exists to use these coals fully while maintaining environmental performance. Due to low combustion temperature, another benefit is a significant reduction in the production and release of nitrogen oxides from those of a conventional coal-fired plant.

In addition, comprehensive Department of Energy studies indicate that the dry, solid byproduct from this process, calcium sulfate, may have useful applications or at least provide a material that can be conveniently disposed of in an environmentally acceptable manner. Based on studies and forecasts by EPRI and Ebasco Services, AFBC generating capacity could reach 25 to 50 gigawatts by the year 2000 which would be 3 to 6.5 percent of the total U.S. electric generation. Approximately 50 to 100 million tons per year of coal would be used in this amount of capacity.

In the East, the capital costs of an AFBC plant are projected to be 10 to 15 percent less in dollars per kW of capacity than a conventional coal-fired unit with scrubbers.

In the West, the capital advantage is projected to be 5 to 10 percent cleaner in mills per kilowatt hour generated while in the West operating costs are projected to be 7 to 12 percent less. Plants burning western coal will only need a small amount of the limestone, if any at all, to meet the environmental standards. Tennessee Valley Authority, Duke Power, and the Commonwealth of Kentucky conservatively estimate that successful AFBC development will save the Nation more than $1 billion and could easily result in a saving of $10 billion over the next 20 or 30 years.

To achieve rapid commercial acceptance by the utility industry this technology needs a utility-scale demonstration to verify reliability, performance, and costs. TVA with significant support from Congress has taken the first major step leading to a utility-scale demonstration by constructing a $68 million, 20 megawatt AFBC plant in Paducah, Ky. Construction activities on this facility are complete, and the unit began shakedown operations in May 1982.

A major test program, jointly funded by EPRI and TVA, is underway to develop the technical and environmental performance data to be used in the design and construction of a demonstration plant. The pilot plant has operated over 1,500 hours and consumed over 7,000 tons of coal and 2,800 tons of limestone.

Based on recent studies, TVA has concluded that the next major step, a utility-scale demonstration facility, can be accomplished by replacing an existing pulverized coal-fired boiler with an AFBC boiler. This approach will accomplish the goals of demonstrating the essential elements of the technology at a significantly lower cost than a new stand-alone facility.

The AFBC demonstration facility will be located in TVA's Shawnee steamplant in Paducah, Ky. To demonstrate this technology, the AFBC boiler could be constructed beside an existing unit at the steamplant as a replacement for the existing boiler. The AFBC boiler would be capable of generating approximately 160 megawatts of electric power and would make maximum use of the existing turbogenerator set and other associated equipment.

The design fuel for the demonstration would be high sulfur Illinois basin coal as typified by Kentucky No. 9. However, fuel flexibility will be considered with testing of alternate fuels during the test program. The preliminary cost estimate for the AFBC demonstration at Shawnee is $200 million.

The schedule as presently proposed allows an adequate amount of time to evaluate the pilot plant test results prior to freezing boiler designs. On this schedule, detailed design and erection of the facility will begin in mid-1984 and will be completed in mid-1989. Operational testing with power to the grid would begin in 1989. This timetable provides the electric utility industry with the option of selecting an AFBC coal-fired plant in the late 1980's or early 1990's to provide added or replacement power to the grid in the middle to late 1990's.

TVA, Duke, and Kentucky have jointly responded to a request by EPRI soliciting a host site for a demonstration of AFBC steam generator in the range of 100 to 200 megawatts. TVA, Duke, and Kentucky have offered to host the demonstration previously discussed and contribute financially to its design, construction, and operation. TVA, Duke, and Kentucky jointly will be pursuing commitment for funds and/or inkind services from EPRI, other utilities, foreign countries or entities, coal companies, equipment vendors, and others in order to secure the resources necessary to build the demonstration facility.

From TVA's viewpoint, AFBC is an important and viable technology which can significantly benefit the Nation. The interest shown by this committee in the development of AFBC technology is of great benefit in pointing out the national significance of the technology, and I appreciate the opportunity to present our program and views, and would be pleased to answer any questions this subcommittee has.

[The prepared statement of Mr. Willis follows:]

STATEMENT OF WILLIAM F. WILLIS
GENERAL MANAGER
TENNESSEE VALLEY AUTHORITY
FOR THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
MARCH 21, 1983

MR. CHAIRMAN: I am William F. Willis, General Manager of the Tennessee Valley Authority (TVA).

I appreciate this opportunity to describe and discuss TVA's fossil energy research and development (R&D) program and, in particular, the development of atmospheric fluidized bed combustion (AFBC) technology. We appreciate the interest shown by Senator Ford and other members of this committee for the National fossil R&D effort, in general, and in the development of AFBC technology, in particular.

TVA's R&D program is intended to provide technologies, techniques, and procedures which reduce the operating costs of the power system. This will come through increases in the power-system reliability, reductions in capital investments, efficient end use of electricity, and development of electric-generating options for future new and replacement capacity. An attempt is made to balance TVA's program by relying strongly on the independent R&D carried out by the Electric Power Research Institute (EPRI), conducting joint efforts with EPRI and other agencies, and carrying out the internal B&D required to solve system or site-specific problems.

Because TVA is one of the Nation's largest coal-burning electric-utility systems, it has several active projects in the fossil-energy area which include experiments in developing rapid measurements of coal quality, economical methods of reducing biofouling in biofouling condensers, and improvements in power plant waste handling, utilization, and disposal. One of TVA's largest efforts, however, has been the development of AFBC to generate steam for electricity production.

This technology offers the utility industry an opportunity to utilize the abundant and less costly coals which are not being used in conventional power plants due to environmental standards. Because the capture of sulfur is inherent during the combustion process, the opportunity exists to use these coals fully while maintaining environmental performance. Due to low combustion temperatures, another benefit is a significant reduction in the production and release of nitrogen oxides from those of a conventional coal-fired plant. In addition, comprehensive Department of Energy studies indicate that the dry, solid by-product from this process (calcium sulfate) may have useful applications or, at the least, provide a material which can be conveniently disposed of in an environmentally acceptable manner. Based on studies and forecasts by EPRI and Ebasco Services, AFBC generating capacity could reach 25 to 50 GW by the year 2000, which would be 3 to 6.5 percent of the total U.S. electric generation. Approximately 50-100 million tons/year of coal would be used in these plants.

In the East, the capital costs of an AFBC plant are projected to be 10-15 percent less (in dollars per kW of capacity) than a conventional coal-fired unit with scrubbers. In the West, the capital advantage is projected to be to be 5-10 percent cheaper (in mills per kWh generated) while in the West, operating costs are projected to be 7-12 percent less. Plants burning western coal will only need small amounts of limestone, if at all, to meet the environmental standards. TVA, Duke Power, and the Commonwealth of Kentucky conservatively estimate that successful AFBC development will save the Nation more than a billion dollars and could easily result in a saving of ten billion dollars over the next 20 or 30 years.

To achieve rapid commercial acceptance by the utility industry, this technology needs a utility-scale demonstration to verify reliability, performance, and costs. TVA, with significant support from Congress, has taken the first major step leading to a utility-scale demonstration by constructing a $68 million, 20-MW AFBC pilot plant in Paducah, Kentucky. Construction activities on this facility are complete, and the unit began shakedown operations in May 1982. A major test program, funded jointly by EPRI and TVA, is underway to develop the technical and environmental performance data to be used in the design and construction of a demonstration plant. The pilot plant has operated approximately 1500 hours and consumed approximately 7000 tons of coal and 2800 tons of limestone.

Based on recent studies, TVA has concluded that the next major step, a utility-scale demonstration facility, can be accomplished by replacing an existing pulverized-coal-fired boiler with an AFBC boiler. This approach will accomplish the goals of demonstrating the essential elements of the technology at a significantly lower cost than a new standalone facility.

The AFBC demonstration facility would be located at TVA's Shawnee Steam Plant in Paducah, Kentucky. To demonstrate the technology, an AFBC boiler would be constructed beside an existing unit at the steam plant as a replacement for the existing boiler. The AFBC boiler would be capable of generating approximately 160 MW of electric power and would make maximum use of the existing turbogenerator set and other associated equipment. The design fuel for the demonstration would be high-sulfur Illinois basin coal, as typified by Kentucky number 9. However, fuel flexibility will be considered with testing of alternate fuels during the test program. The preliminary cost estimate for the AFBC demonstration at Shawnee is $200 million.

The schedule as presently proposed allows an adequate amount of time to evaluate the pilot plant test results prior to freezing boiler designs. On this schedule, detailed design and erection of the facility will begin in mid-1984 and will be completed by mid-1989. Operational testing with power to the grid would begin in 1989. This timetable provides the electric utility industry with the option of selecting an AFBC coal-fired plant in the late 1980s or early 1990s to provide added or replacement power to the grid in the mid-to-late 1990s.

TVA, Duke, and Kentucky have jointly responded to a request by EPRI soliciting a host site for a demonstration of an AFBC steam generator in the range of 100 to 200 MW. TVA, Duke, and Kentucky have offered to host the demonstration previously discussed and contribute financially to its design, construction, and operation. TVA, Duke, and Kentucky, jointly, will be pursuing commitments for funds and/or inkind services from EPRI, other utilities, foreign countries, coal companies equipment vendors, and others in order to secure the resources necessary to build the demonstration facility.

From TVA's viewpoint, AFBC is an important and viable technology which can significantly benefit the Nation. The interest shown by this committee in the development of AFBC technology is of great benefit in pointing out the national significance of this technology.

I appreciate the opportunity to present our program and views. I would be pleased to answer any questions this subcommittee has.

Senator **Ford** [presiding]. Mr. Willis, I thank you very much for your very fine and concise statement. In order to conserve time I want to ask three or four questions for the record here today, and then I would like to submit to you a list of questions, approximately 10 or 12, that I would like for you to respond to in writing if you would for the record.

Mr. **Willis**. We would be very glad to do that, sir.

Senator **Ford**. Mr. Willis, would you describe the environmental advantages of the technology that would be used in this project? How do these advantages depend on the quality of the coal that can be used and what kind of coal is the project designed to use and so forth?

Mr. **Willis**. One of the reasons we are so interested in it, most of our coal comes from the central basin coal in Kentucky, in that area. It has high AH content and high sulfur. One of the principal advantages from an environmental standpoint of this technology is that you don't have to depend on very expensive flue gas scrubbers for meeting our very low sulfur coal supply for meeting environmental standards.

The reaction of the sulfur dioxides with the calcium sulfate in the limestone produces a calcium sulfate that drops out of the dry product in the bottom ash and that way you can burn a lower grade coal, a less expensive coal with a high sulfur coal. That is the main environmental benefit. Of course, by having a lower combustion temperature you are not at the combustion temperatures or reaction temperatures of the nitric oxides so you eliminate being troubled by that problem also in this process.

Another byproduct is the waste stream which we believe to be handled in a more environmentally acceptable manner because the dry product is not very toxic, and also it may have some application to agriculture, building, or the cement industry also. It could be used as a byproduct.

Senator **Ford**. Mr. Willis, how do you currently plan to finance the project? What are the respective contributions of the present participants and what is the status of the commitment by these participants?

Mr. **Willis**. Sir, as I mentioned, the project is estimated to cost about $200 million, and Tennessee Valley Authority, Duke Power, and the State of Kentucky have made a proposal to EPRI that if EPRI will put up $100 million, we will commit to raising the other. We have already made a commitment, Duke Power has made a commitment of $10 million. The State of Kentucky has made a commitment of $10 million out of their technology research fund, and TVA has made a commitment of $40 million to the process.

Senator **Ford**. How many?

Mr. **Willis**. $40 million, and the rest we intend to go to the utility industry, coal companies, vendor suppliers, and others to raise the rest of the required money to meet the funding requirement.

Senator **Ford**. You indicate in your statement a starting date and a completion date. Could you supply the committee with a chart of some kind, and that will be one of the questions, showing your projected schedule for completion, indicate the key milestones in that schedule and what you estimate is the likelihood of slippage in the schedule, and then also maybe some overruns or slippage in cost? Can you do that for the record?

Mr. WILLIS. Yes, we can. I would like to leave the committee a copy of a booklet on it that has such a chart, but we will supply one for the record, and I will make some speculation on how comfortable we feel with the estimate.

Senator FORD. That's fine. Mr. Willis, what is your contingency plan for financing the project should you lose important elements of the currently planned financing arrangement?

Mr. WILLIS. Well——

Senator FORD. Have you identified any alternative financing?

Mr. WILLIS. We feel very confident that we will be able to raise this financing in the manner we have. We haven't developed a specific contingency plan, but I am sure that if we had a financial problem with raising that money we would be talking to the committee and others about arrangements that may be necessary, but we feel pretty comfortable that we may be able to do this, but you never know exactly until you get out and make the solicitations how much you are going to get.

Senator FORD. Let me ask you this. I introduced a piece of legislation that has gotten some support, and would it hinder you in trying to secure funding to say well, you have got it from Congress because it says only if you cannot secure the funds? Do you see any problem?

Mr. WILLIS. I don't know that that hinders.

Senator FORD. Would it jeopardize somebody coming in who ought to be coming in from the private sector?

Mr. WILLIS. I don't know if it would or not. I would hate to speculate on that. I know the committee and you appreciate that we are just not in the position right now to discuss the question of Federal financing of any part of the project, and to spell out how we plan to go about getting it, but I think it would be most helpful if the committee could in an appropriate way perhaps in your committee report on this authorization bill express your views on what you feel are the merits of this project, and I hope we have convinced you the merits are very good.

Senator FORD. You have convinced me earlier.

Mr. WILLIS. That's the value of this demonstration project, what it means to the electric utility and the coal industry and the goal of getting a cleaner environment along all with that, and I would also note for the record that TVA would not require a specific authorization bill or legislation to receive any appropriations if that came about later on given the existing authority that we have in the TVA Act of 1933, so I just wanted to add that.

Senator FORD. Mr. Willis, I asked you the negative question rather than the positive question, and so the other side of that negative question would be the positive approach, that the investors once they get beyond 75 percent of it can feel confident with this piece of legislation that the plant will go forward, the 200-megawatt plant will go forward, so there is some positive side to having legislation when you know once you get past the $150 million figure, and you are basically there now, that the plant will be built if this piece of legislation goes through.

Mr. **Willis**. Yes, sir. We very much plan for that plant to be built, and we are going to see that it gets done, whatever is necessary.

Senator **Ford**. The chairman has left. Senator Melcher, do you have any questions for Mr. Willis?

Senator **Melcher**. I want to tell you, Mr. Willis, that it is refreshing for somebody to come in here and tell us that they believe we can do a better job in generating electricity from coal, and I want to commend you and TVA as well as EPRI and Duke and Kentucky for going ahead and leading the way to better utilization of coal and clean air environment. I commend you very highly, and I encourage you to keep with the program.

I want to express my support for you and TVA's efforts. Thank you very much.

Mr. **Willis**. I appreciate that.

Senator **Melcher**. And Senator Ford and Senator Huddleston.

Senator **Ford**. You cover the waterfront when we're right!

Senator **Melcher**. Right.

Senator **Ford**. Mr. Willis, we do thank you. The subcommittee stands adjourned until the call of the Chairman.

[Whereupon, at 11:45 a.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX IV

ANSWERS TO ADDITIONAL QUESTIONS SUBMITTED FOR THE RECORD FROM MR. MARES

JAMES A. MC CLURE, IDAHO, CHAIRMAN

MARK O. HATFIELD, OREG.
LOWELL P. WEICKER, JR., CONN.
PETE V. DOMENICI, N. MEX.
MALCOLM WALLOP, WYO.
JOHN W. WARNER, VA.
FRANK H. MURKOWSKI, ALASKA
DON NICKLES, OKLA.
CHIC HECHT, NEV.
JOHN H. CHAFEE, R.I.
JOHN HEINZ, PA.

J. BENNETT JOHNSTON, LA.
HENRY M. JACKSON, WASH.
DALE BUMPERS, ARK.
WENDELL H. FORD, KY.
HOWARD M. METZENBAUM, OHIO
SPARK M. MATSUNAGA, HAWAII
JOHN MELCHER, MONT.
PAUL E. TSONGAS, MASS.
BILL BRADLEY, N.J.

MICHAEL D. HATHAWAY, STAFF DIRECTOR
CHARLES A. TRABANDT, CHIEF COUNSEL
D. MICHAEL HARVEY, CHIEF COUNSEL FOR THE MINORITY

United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

March 25, 1983

The Honorable Jan W. Mares
Assistant Secretary
Fossil Energy
U.S. Department of Energy
Washington, D.C. 20585

Dear Secretary Mares:

In following up on the hearings of the Subcommittee on Energy Research and Development that were held on March 21, 1983, we are asking for your response to the enclosed additional questions.

We very much appreciated your appearance before the Subcommittee and look forward to your response to this request. Thank you for your cooperation.

Sincerely,

Pete V. Domenici
Chairman, Subcommittee on
Energy Research and Development

PVD/pgh
Enclosures

Questions for Jan Mares from Senator Pete V. Domenici

1. Please provide an update on the status of the Great Plains Coal gasification project. Is it on schedule? Is it under cost? What has been the effect of the falling oil price in the economics of this project? How has the falling price of oil affected the estimated return on investment for the sponsors of this project? Have the sponsors of this project expressed concerns about the viability of this project to the Department of Energy. Have there been discussions regarding the technical default of this project between the sponsors and the Department of Energy? Why has the Department failed to communicate concerns about this project to the Congress?
2. Has the Department of Energy had discussions with the Synthetic Fuels Corporation regarding the financial status of the Great Plains Project? Has the Department of Energy given consideration to renegotiation of the terms of the agreement for the loan guarantee of this project? Does the Department of Energy have the authority to negotiate a price guarantee for this project? Does the Department of Energy have the authority to transfer this project to the Synthetic Fuels Corporation?

Questions for Jan Mares from Senator John Warner

1. In cleaning up the flue gases from coal boilers we come up with a sludge which is very difficult to handle. Could you tell us what you are doing to develop a process that would avoid this waste disposal problem?
2. I note that the Department has requested an increase for research into enhanced oil recovery. Could you explain to the Subcommittee why it is you believe the Department of Energy should be doing research in this area? Do you have some particular expertise that you believe the oil companies do not?

3. Your research request for shale oil has been reduced. That is such a vast resource, more oil than in Saudi Arabia, that I believe we should be doing all we can to make sure that that resource can be exploited. In view of the fact that the falling price of oil is making the economics of shale oil development more difficult, don't you believe that research by the Department to more economically exploit that resource is in order?

Department of Energy
Washington, D.C. 20585

April 14, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

Following the March 21, 1983, hearing of the Subcommittee on Energy Research and Development, you submitted additional questions to Assistant Secretary Jan W. Mares. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bc: Mr. Al Astrin
Committee Staff

Senate Sub. on Energy
Research and Development
Asked by Sen. Pete Domenici
Hearing of March 21, 1983

Question 1a: Please provide an update on the status of the Great Plains Coal gasification project. Is it on schedule? Is it under cost?

Answer: The overall percentage of completion for the Great Plains Coal Gasification Program (GPCGP) is 70.8 percent as of February 28, 1983, or 4.8 percent behind schedule. The planned percentage of completion was 75.6 percent. Engineering was 2.3 percent ahead of schedule and procurement was 6.1 percent behind. Construction is currently over 50 percent complete.

The 57th disbursement from the Federal Finance Bank of $6.5 million against the loan guarantee was approved on March 29, 1983, for payment on March 31, 1983. Total disbursements through March 1983 are $622.5 million. Current estimates indicate that the program is within cost and may be completed under the original estimate of $2,112,703,000.

Question 1b: What has been the effect of the falling oil price in the economics of this project?

Answer: Oil price is one of the major factors that impact the economic viability of this project. Others include tax laws, natural gas pricing, construction cost, operating rate, by-product sales revenues, coal price to the project and FERC contractual rulings. DOE, as well as Great Plains Gasification Associates (GPGA), is presently examining the impact of projected oil prices under various scenarios. Although the projected prices of world oil are currently lower than when DOE and GPGA signed the loan guarantee for this plant, all parties to the agreement have continued their commitment to the project. Because of the uncertainties associated with projected trends in world prices, no definitive answer can be provided other than the fact that the price of project gas is capped by formulas related to price of No. 2 fuel oil, imported natural gas and domestic natural gas. Project evaluation will be continued based on the best information available.

Question 1c: How has the falling price of oil affected the estimated return on investment for the sponsors of this project?

Answer: As indicated previously, the price of project gas is capped by the price of No. 2 fuel oil and natural gas. It is uncertain how steep the oil and gas price drop will be; therefore, it is uncertain how much estimated return on investment for the sponsors will be affected. This will continue to be evaluated along with the other factors that impact the project's viability. As of this point in time, the Partnership has informed DOE that compared with a projected return of equity within 9 years as anticipated by the Information Memorandum, the current cash flow projections (using preliminary NEPP-IV mid-range estimates) indicate that equity would not be returned for 16 years. Notices have been received from the 5 Partners that they believe conditions exist that would permit the Partners to vote to terminate. (i.e., the partnership would be unable to pay back Contributed Equity in ten-year period following In-Service Date), however the Partners do not intend to exercise their right to terminate participation in the project at this time.

Question 1d: Have the sponsors of this project expressed concerns about the viability of this project to the Department of Energy?

Answer: Both DOE and the sponsors are concerned about the uncertainties of factors affecting the project. The sponsors have also indicated that they do not want to abandon the project. Both DOE and GPGA continue to evaluate the situation. On the basis of their evaluation, the partners in GPGA may make proposals on the project. If so, DOE will consider them.

Question 1e: Have there been discussions regarding the technical default of this project between the sponsors and the Department of Energy?

Answer: Discussions to date have only centered around the review of the provision of the loan guarantee to meet changing conditions and the establishment of reasonable parameters for the conduct of analyses for various projected scenarios to include optimistic and pessimistic forecasts of oil prices.

Question 1f: Why has the Department failed to communicate concerns about this project to the Congress?

Answer: The Department reports on the status of the Great Plains Coal Gasification Project as a part of the semiannual report to the Congress on the Alternative Fuels Production Program. The last report was Report No. 6, dated December 1982, which was forwarded to Congress on January 27, 1983. There has been no reason to make a special report on the project since that time because DOE is still evaluating the impact of various forecasts of oil prices on the project. In addition, DOE has not identified any specific concerns regarding this project that would warrant a special report to Congress.

Senate Sub. on Energy
Research and Development
Asked by Sen. Pete Domenici
Hearing of March 21, 1983

Question 2a: Has the Department of Energy had discussions with the Synthetic Fuels Corporation regarding the financial status of the Great Plains Project?

Answer: DOE and SFC have not had specific discussions related to the various pricing scenarios presently being analyzed. However, DOE and SFC coordinate closely on all projects. For example, and SFC representative at the invitation of DOE regularly attends project progress reviews of GPCGP.

Question 2b: Has the Department of Energy given consideration to renegotiation of the terms of the agreement for the loan guarantee of this project?

Answer: The Department has been reviewing it's authorities to modify the Loan Guarantee Agreement and analyzing the impact of oil prices, postulated under various scenarios, on the projects economic viability. At present no proposal for renegotiation has been made by Great Plain Partnership.

Question 2c: Does the Department of Energy have the authority to negotiate a price guarantee for this project?

Answer: Section 7(c) of the Federal Nonnuclear Energy Research and Development Act of 1974, as amended, Public Law 93-577 (NNA) authorizes the implementation of price support programs subject to the enactment of specific legislation by the Congress. Therefore, in order for DOE to provide price support assistance, it would be necessary to obtain Congressional authorization as well as appropriations. The DOE could award such assistance under the NNA.

Question 2d: Does the Department of Energy have the authority to transfer this project to the Synthetic Fuels Corporation?

Answer: Public Law 97-100, enacted on December 23, 1981, specified that the provisions of Public Law 96-304 regarding transfer of projects to the SFC from the Department of Energy shall not apply to any demonstration projects authorized pursuant to the Federal Nonnuclear Energy Research and Development Act, as amended. Therefore, DOE does not have the authority to transfer this project to the SFC.

Senate Sub. on Energy
Research and Development
Asked by Sen. John Warner
Hearing of March 21, 1983

Question 1: In cleaning up the flue gases from coal boilers we come up with a sludge which is very difficult to handle. Could you tell us what you are doing to develop a process that would avoid this waste disposal problem?

Answer: Sludge is the waste product produced by the flue gas desulfurization systems in use today to remove most sulfur from exhaust gases. The DOE Control Technology and Coal Preparation activity encompasses a two-fold approach towards ameliorating the sludge waste disposal problem. One approach is directed at research and development of combined SO_x/NO_x/particulate flue gas cleamup systems which produce a dry disposable or useable waste. There processes will not only eliminate the sludge disposal problem, but also will remove the sulfur oxides (SO_x), nitrogen oxides (NO_x) and particulates from the flue gases. The second effort is directed at investigating other new and novel fixation/stabilization processes which will provide for improved economics, while simultaneously disposing of the sludge in an environmentally acceptable manner.

In the combustion area, programs include research on both atmospheric and pressurized fluidized bed systems which remove sulfur without the formation of the troublesome sludge. And, we are engaged in research on new and novel methods to clean sulfur from coal during the preparation stage, before it is combusted.

Senate Sub. on Energy
Research and Development
Asked by Sen. John Warner
Hearing of March 21, 1983

Question 2: I note that the Department has requested an increase for research into enhanced oil recovery. Could you explain to the Subcommittee why it is you believe the Department of Energy should be doing research in this area? Do you have some particular expertise that you believe the oil companies do not?

Answer: Industry emphasis in Enhanced Oil Recovery (EOR) is on those technologies that have a proven track record — such as polymer and steam flooding — rather than on the advanced methods, even though the recovery potential of the latter may be far greater. The bulk of industry expenditures is in field operations where there is an attempt to optimize a chosen methodology for a given site. Unlike with coal our work is primarily at universities, National Laboratories and Energy Technology Centers. Through conferences, workshops and meetings with industry R&D people we are learning and thus focusing our funded work on areas that are fundamental to further technology advances but are not being addressed by industry.

Some of the more advanced and more efficient EOR techniques are not widely used today because further technology development is required to improve their reliability. Since the application of these EOR techniques requires significant investment, industry tends to apply the more predictable methods even though they may not recover a large percentage of the residual oil. The more advanced techniques have the potential for high residual oil recovery but not enough is known about the chemistry and physics of recovery to make adequate predictions as to performance. The Government has an appropriate role in doing the basic and fundamental research needed to better understand and predict the performance of these advanced techniques. We believe this improved understanding will lead to new processes that are economically competitive with existing EOR commercial technology.

The Government role should be that of a catalyst. By doing fundamental research on theoretical aspects and modeling of techniques for enhanced oil recovery, we hope to provide a sufficient technical foundation in critical areas for industry to design, scale-up and deploy new petroleum recovery processes on their own. Successful application of the more advanced EOR techniques with attendant high residual oil recovery can dramatically expand our domestic reserves (typically 2/3 of the oil remains in the reservoir after primary and secondary recovery efforts are completed).

Also, unlike individual oil companies, the Government is in a unique position to collect and analyze data from a national perspective. The EOR data base already covers 650 projects and is the only such source in the country. DOE is also the focal point for annual reporting on over 400 tests initiated under ERA incentive programs. The National Petroleum Council, in fact, uses the DOE data base and the predictive models for EOR. In addition, the Government has demonstrated that it can bring certain expertise to bear in EOR. For example, a highly successful project initiated by DOE on the development of a downhole steam generator conducted at Sandia National Laboratory is now being pursued by industry.

Senate Sub. on Energy
Research and Development
Asked by Sen. John Warner
Hearing of March 21, 1983

Question 3: Your research request for shale oil has been reduced. That is such a vast resource, more oil than in Saudi Arabia, that I believe we should be doing all we can to make sure that that resource can be exploited. In view of the fact that the falling price of oil is making the economics of shale oil development more difficult, don't you believe that research by the Department to more economically exploit that resource is in order?

Answer: We agree that a strong research program in oil shale is in order. The Department of Energy's program has the objective of providing industry with scientific and engineering data bases for developing more economic and environmentally acceptable processes that should lead to increased exploitation of the nation's vast oil shale resource. Our research is a balanced approach addressing factors concerning increased recovery efficiency and improved economics. Also, factors that can improve the economics of controlling environmental emissions are being pursued as a part of our Environmental Mitigation efforts.

The overall budget request for oil shale occurred primarily because of termination of an oil shale demonstration program which is now ready for commercialization by industry.

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

MONDAY, MAY 2, 1983

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, D.C.

The subcommittee met, pursuant to notice, at 11 a.m., in room SD-366, Dirksen Office Building, Hon. J. Bennett Johnston, presiding.

Present: Senators Johnston and McClure.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, A U.S. SENATOR FROM THE STATE OF LOUISIANA

Senator Johnston. Good morning.

The hearing will come to order. This morning we have oversight hearings on the President's proposed budget for fiscal year 1984 for the Department of Energy's nuclear waste activities program.

I am happy to welcome this morning as our first witness Mr. Robert L. Morgan, who is the Project Director of the Nuclear Waste Policy Act Project Office.

Mr. Morgan.

Mr. Morgan. Thank you, Mr. Chairman. It's a pleasure to be here this morning. Rather than go through my statement, may I submit it for the record, sir, and briefly summarize it?

Senator Johnston. That will be done.

Mr. Morgan. Thank you, Mr. Chairman.

STATEMENT OF ROBERT L. MORGAN, PROJECT DIRECTOR, NUCLEAR WASTE POLICY ACT PROJECT OFFICE, DEPARTMENT OF ENERGY

Mr. Morgan. As you know, in late January the Secretary did organize a nuclear waste project office. He established that office, reporting to the Secretary, as an early indication of compliance with the act.

My understanding is that we are in the process of getting a permanent director and then the Office of Civilian Radioactive Waste Management will be formally activated.

Senator Johnston. You say you are in the process of getting. What does that mean?

Mr. MORGAN. We are currently going through the organizational development process for the organization that is required in the act. We are outlining that organization and as soon as that is completed, it will be forwarded to the Secretary for his approval, sir. After the Secretary approves the organization plan we will organize on a permanent basis.

I believe that shortly there should be a nominee coming forward for the director's job.

Senator JOHNSTON. There is a search going on for the nominee?

Mr. MORGAN. Yes, sir.

Senator JOHNSTON. I see.

Mr. MORGAN. In the area of establishing guidelines for repository site selection, sir, we issued draft guidelines on February 7. We had hearings from March 4 to March 21; and the comment period closed on April 7.

As you know, the requirement is that we provide final guidelines by July 7. We are looking at a consultation process with the States and with NRC. As you know, NRC must concur in those guidelines.

We are thinking that to do the job right, we may be slipping that date slightly. We hope that it is not more than a month.

In the disposal contract area, we published the final contract on April 18; and, as you know, effective April 7, we started collecting fees from the utilities for the nuclear waste fund.

We have held hearings or are in the process of holding hearings at all the potential candidate sites for nomination. We will not—I repeat not—nominate any sites until after the guidelines are final and we have final environmental assessments for each of the spacific sites that are affected.

The 1984 request for the nuclear waste fund is $306 million, commercial waste management is $6.3 million, and spent fuel technology is $5 million; for a total of $318 million. I think you have those documents. That would just summarize my statement at this point.

[The prepared statement of Mr. Morgan follows:]

Statement of Robert L. Morgan
Project Director
Nuclear Waste Policy Act Project Office
Department of Energy
Before the Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
May 2, 1983

Mr. Chairman and Members of the Subcommittee:

I am pleased to appear before you today to discuss the Department of Energy's (DOE's) FY 1984 commercial nuclear waste management and spent fuel storage budgets and programs. These programs are provided for in the Nuclear Waste Policy Act of 1982 which the President signed into law on January 7, 1983. I am very grateful to this Committee for its help in passing the Act. I also ask for your continued support and cooperation in helping implement the major national objectives of this program.

Secretary Hodel is determined that we mobilize the necessary resources to assure that a mission-oriented coordinated effort is conducted to meet the elaborate set of near-term requirements and actions that are required to be accomplished within the first 180 days by this Act. However, the Secretary and I are also equally committed to following a course that addresses all of the institutional issues and concerns that are of critical importance to the success amd ultimate public acceptance of this program. Our concern for adhering to the institutional processes, especially consultation and cooper-tion with State and local Governments, will receive the same consideration as our concern for adhering to the program's technical requirements.

Shortly after enactment of the Nuclear Waste Policy Act, the Secretary established a Nuclear Waste Policy Act Project Office. As Director of this Project Office, I am responsible for DOE's initial activities to implement the Act. This Project Office will be operational until the Office of Civilian Radioactive Waste Management, established by Section 304 of the Act, is activated. The Project Office is structured as depicted in Attachment 1. It should be clearly understood that this Project Office is not a permanent organizational structure; it was solely established to implement the provisions of this Act that require action in the near term.

PROGRAM BUDGET

The Project Office is responsible for activities in three major budget categories: the Nuclear Waste Fund; Commercial Waste Management; and Spent Fuel Technology. The funding for these activities is summarized below.

Nuclear Waste Policy Act Project Office
Budget Summary
($ in Millions)

Program	FY 1982 Actual	FY 1983 Contin. Resol.	FY 1984 Congr. Request
Nuclear Waste Fund.	-	217.3	306.7
Commercial Waste Managementa/............	190.3	24.0	6.3
Spent Fuel Technologya/..................	6.8	6.4	5.0
Project Office Total.....................	$197.1	$247.7	$318.0

a/ Denotes portions managed by the project office.

The Act requires major efforts in two primary areas: (1) disposal of spent fuel and high-level waste; and (2) storage of spent fuel and high-level waste.

Nuclear Waste Fund

Efforts in the disposal area as well as actual disposal services, are to be financed by fees collected from utilities and placed into a Nuclear Waste Fund. To cover disposal activities until there are collections in the Fund, the FY 1983 Continuing Resolution contains $217.3 million. In FY 1984, we are requesting an appropriation of $306.7 million to cover disposal activities. The Nuclear Waste Fund has become operational. We are in the process of transferring all unexpended appropriations as of January 1, 1983, into the Fund. Initial revenues of $98 million are projected to partially offset this appropriation in FY 1983. During FY 1984 and out years, revenue flow will approximate $40 million monthly, based on a 1 mill per kilowatt hour charge for electricity generated by civilian reactors, equalling a half billion dollars on an annual basis. In addition, for existing spent fuel in inventory at reactor sites prior to April 7, there is anticipated revenue amounting to approximately $2 billion

Commercial Waste Management

Current waste management activities, subseabed R&D and supporting studies, are not eligible for coverage under the Waste Fund and will remain as an element of our annual commercial waste request. In FY 1984, we are requesting $6.3 million for these activities.

The Department's FY 1983 Continuing Resolution includes $3.5 million plus $600,000 of unexpended FY 1982 funds for work in the monitored retrievable storage area. The 1983 efforts will focus on the selection of specific storage concepts based, as much as possible, upon the previous MRS studies conducted by the Department and industry.

Since the Department's FY 1984 budget was prepared prior to enactment of the Act, no FY 1984 funds for MRS were requested. We are currently reviewing funding alternatives to enable the Department to proceed with developing the one detailed design for its preferred site/concept option and conceptual designs for the four alternate site/concept options; the environmental assessment including a comparison of the five design/site options; and the supporting Monitored Retrievable Storage system plans.

Spent Fuel Technology

The Act provides for Federal storage of up to 1900 metric tons of spent fuel for those utilities that the Nuclear Regulatory Commission (NRC) determines cannot reasonably provide sufficient additional on-site storage. This Federal storage is to be financed through utility user fees that are placed into an Interim Storage Fund. The Act also provides for cooperative research, development and demonstration activities at utility sites and Federal sites. These activities are to be jointly funded by the utilities and the Federal Government. Lastly, there are generic research and development (R&D) activities in the spent fuel area that are funded from general appropriations. The FY 1983 appropriation under the Continuing Resolution was $6.4 million for the generic Spent Fuel Storage Program, and the FY 1984 request is $5.0 million. The Interim Storage Fund may become operational in FY 1983; however, we currently do not foresee a need to transfer any FY 1983 appropriations into the fund; and consequently, the exact date for execution of the fund may await a signal from a utility that it needs storage services and wishes to sign a contract with DOE for interim storage.

With your permission, Mr. Chairman, I shall now highlight the key provisions of the Act and then describe how these provisions are being implemented.

KEY PROVISIONS OF THE NUCLEAR WASTE POLICY ACT OF 1982

Under the provisions of this Act, mandated milestones have been established in the areas of fund management, geologic repository, monitored retrievable storage and spent fuel storage. Specifically, the Act established the following activities in each of these areas:

Fund Management

The Secretary is authorized to enter into contracts with owners or generators of spent nuclear fuel or high level waste for disposal services by DOE in return for the payment of fees by the owners or generators. The contracts must be executed by June 30, 1983.

Geologic Repository

The Act sets forth a rigorous schedule sequence and associated processes for siting, licensing and constructing geologic repositories for the disposal of nuclear waste. They are as follows:

- General guidelines for the recommendation of potential repository sites will be issued by July 1983.
- Environmental Assessments for the sites to be nominated must be issued.
- Five or more sites must be nominated for detailed site characterization.
- Three sites must be recommended to the President no later than January 1985 for detailed characterization.

- The President must recommend to Congress by March 1987 the site to be designated as the first repository.

- NRC must act on the license application no later than August 1990. (Assuming DOE License submittal by August 1987)

- Three sites for detailed characterization of the second repository must be recommended to the President by 1989.

- The President must submit a recommendation for the second repository site to Congress by March 1990.

- In return for payment of fees, DOE will dispose of nuclear waste beginning no later than January 1998.

The Act also specifies procedures for participation by States and Indian Tribes. These procedures include:

- States with potentially acceptable sites for the first repository are to be notified by April 1983.

- At the request of a notified State, procedures for consultation and cooperation must be specified in written agreements.

- Public hearings are required in States in the vicinity of potential repository sites.

- A State may submit to Congress a notice disapproving of the site finally designated as the repository. Disapproval can only be overridden by a Joint Resolution of Congress.

- o Grants and impact aid must be made available to affected States and affected Indian Tribes.
- o The Act also calls for a program of research and development, including an underground Test and Evaluation Facility (TEF).

Monitored Retrievable Storage

Provisions are made in the Act for a Monitored Retrievable Storage (MRS) Program. Under this Program, DOE must:

- o Submit by July 7, 1983, a report to Congress describing the research and development activities necessary to develop the MRS proposal.
- o Complete a detailed proposal by June 1985 for the construction of one or more MRS facilities.

Spent Fuel Storage

The Act requires a Research and Development Program for spent nuclear fuel storage. Specifically, the Act requires that by January 7, 1984, DOE select one to three reactor sites for a licensed demonstration with utilities of dry storage technologies.

A Federal Interim Storage Program is also called for in the Act. Under this program, NRC will determine eligibility for Federal Interim Storage and the Act requires DOE to:

- o Provide not more than 1900 metric tons of storage capacity for civilian reactors that cannot reasonably provide sufficient at-reactor capacity.
- o Submit by July 7, 1983, a fee study for Federal Interim Storage.

The Act also requires that a program be undertaken to cooperate with and provide technical assistance to foreign nonnuclear weapon states in the field of spent fuel storage and disposal

IMPLEMENTATION OF THE NUCLEAR WASTE POLICY ACT

Fund Management

As of April 7, 1983, DOE began charging all utilities a fee of one mill per kilowatt hour of electricity generated on or after April 7 by civilian nuclear power reactors for disposal of their spent fuel and high-level waste. Based on this charge, revenue flows will approximate $40 million per month, or approximately a half billion dollars per year. For existing spent fuel, DOE has developed a four-tiered fee structure based on extended fuel burnup with three payment options. Spent fuel in inventory at reactor sites prior to April 7 will provide anticipated revenues amounting to approximately $2 billion.

DOE published on April 18, 1983, a standardized contract which will be used as the formal agreement between DOE and utilities to dispose of spent fuel. Owners and generators of spent fuel or high-level waste have until June 30, 1983, to execute the contract with DOE. The contract sets forth terms and conditions, as well as financial procedures and a fee structure, for disposal services.

Disposal Activities

The Act establishes a step-by-step process by which the President, the Congress, the States, affected Indian Tribes, the U.S. Department of Energy and other Federal agencies can work together in the siting, construction and operation of a high-level nuclear waste repository. One of our priorities is to strengthen consultation and cooperation between DOE and affected States and affected Indian Tribes. The Act provides a firm basis for this cooperation. In this regard, we have been consulting regularly with State, local and tribal officials and have held a number of meetings to discuss specific concerns. In addition, numerous public hearings and public meetings have been held to explain our efforts to State officials and to the public.

Siting Guidelines

As an early step, the Act requires that the DOE issue within 180 days of enactment, Site Selection Guidelines for the recommendation of sites for a repository. On February 7, 1983, the proposed Guidelines were published in the Federal Register for public review and comment. These Guidelines will be used to identify and nominate sites for characterization.

To facilitate public involvement, we held public hearings during the Guidelines comment period. These hearings were held in March in Chicago, New Orleans, Washington, D.C., Salt Lake City, and Seattle. Extensive comments were received and we are now in the process of responding to these comments. We intend to meet and work with interested States to address their specific comments and concerns prior to submitting the final Guidelines to the Nuclear Regulatory Commission for concurrence.

First Repository

DOE is required by Section 116(a) of the Act to identify States having potentially acceptable sites for waste reporsitory. A potentially acceptable site is defined by the Act as "any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the Department undertakes preliminary drilling and geophysical testing for the definition of site location." The Department has identified and has notified the Governors of six States--Louisiana, Texas, Utah, Mississippi, Nevada and Washington--as having a potentially acceptable site for the first repository

The Act requires that for each site under consideration, DOE conduct public hearings to solicit comments on our intent to nominate sites and to receive recommendations on issues to be addressed in the environmental assessment and in any site characterization plan to be used if the site is approved by the President. DOE will hold these hearings in the vicinity of every identified potentially acceptable site. The specific dates and locations for these hearings have been established after consultation with State representatives. Public hearings were held in the State of Washington, March 25; in Nevada, March 30 and 31; Mississippi, April 28 and 29; and are scheduled again in Mississippi and in Utah, Louisiana and Texas in early May.

The next step under the Act is DOE's initial nomination of at least five sites for site characterization. The nomination will be based on a consideration of the final Guidelines and the environmental assessments to be prepared for each of the five nominated sites, and followed by a recommendation of three candidate sites for detailed site characterization to the President for his approval. Based upon data from this characterization, DOE will recommend to the President by March 31, 1987, one of these three sites to become the first waste repository.

Geologic Media R&D

While a great deal of attention has been focused recently on the implementation of the Act, significant and impressive technical progress in the R&D program continues to be made. FY 1982 and early FY 1983 produced many major accomplishments in the site exploration phase of the three primary geologic media being considered for the first repository: basalt, tuff and salt.

In basalt, an exploratory shaft site was selected and the NEPA documentation was completed prior to the enactment of the NWPA. The principal borehole was drilled to the desired repository level and confirmatory hydrologic testing was initiated. Designs needed to start the exploratory shaft were finalized, and construction was started with the drilling of the starter hole in November 1982. Further drilling has been discontinued and will not resume until an Environmental Assessment based upon Final Guidelines is issued.

In tuff, the conceptual design for an exploratory shaft was completed and a location for the shaft was selected. Drilling and testing of several boreholes to understand the geohydrologic conditions continued. The principal borehole was started and completed.

In salt, project exploration achieved definition of specific locations and preliminary study plans in the Gulf Coast salt domes and in the Paradox Basin bedded salts of Utah. In the Palo Duro basin of the Texas panhandle, small areas were defined, and an extensive series of deep drill holes and geophysical tests are nearing completion according to a DOE/State agreement. A waste package conceptual design and the preliminary salt exploratory shaft design were completed.

In FY 1984, the program begins a transition from the research phase to the engineering development phase. In basalt, we anticipate drilling of an exploratory shaft will resume and repository design studies will continue. In tuff, if recommended for site characterization, the exploratory shaft mining will be inaugurated. In salt, at those sites recommended for site characterization, drilling of an exploratory shaft will start and site specific hyrdologic and geologic testing will continue. Additionally, R&D will continue on waste package design, materials characterization and transportation studies. The aim of this overall work is to develop the data to assist a Presidential site selection and subsequent repository license application for a first repository in the mid-to-late 1980's.

Second Repository

As part of the Department's efforts in support of the siting of a second repository, on February 10, 1983, the Secretary sent letters to the Governors of 17 States informing them that DOE will conduct more detailed research to determine if their States could be potentially acceptable as a second repository. These States are: Wisconsin, Michigan, Rhode Island, Minnesota, Massachusetts, South Carolina, New Hampshire, Vermont, Maine, New Jersey, New York, Georgia, North Carolina, Maryland, Virginia, Pennsylvania and Connecticut. The studies being conducted in these states are in formations of crystalline rock, such as granite. The management of crystalline rock site exploration has been strengthened by establishment of a field project office. Regional literature based on geohydrologic data surveys will be completed in the latter part of FY 1983 in these seventeen states in the eastern United States. These studies will define specific rock units for further field studies in FY 1984 and beyond.

Terminal Isolation Generic R&D and Supporting Studies

The objective of the Commercial Waste Management program is to support technology related to the long-term management and disposal of commercial radioactive waste. Specific activities include: (1) basic generic R&D for the geologic disposal of commercial waste; and (2) studies to support the combined commercial waste management activities; and (3) efforts toward international and technical review coordination. As stated earlier, while the Project Office is managing these activities, the activities are funded under the Commercial Waste Management Program and not by the Nuclear Waste Fund.

Current activities include development of measurement methods for laboratory testing of host rocks and radionuclide migration through rocks. An integrated generic performance assessment model is being developed to predict potential release and migration rates from a repository. The preliminary waste acceptance. criteria and specifications are being defined. Development and testing of repository backfill systems is being completed. Equipment and instrumentation for in-situ testing and performance monitoring is being developed and tested.

The only generic R&D effort remaining in the Terminal Isolation program in FY 1984 is associated with alternative disposal concepts R&D which currently is the subseabed research effort. This effort is directed toward establishing the feasibility of the subseabed disposal concept. If feasibility is established, it will provide the basis for removal of institutional restrictions on disposal in subseabed. In FY 1983 a technical status report will focus on the critical feasibility issues for the subseabed activities including the completion of sediment models for predicting the effects of emplaced waste. A free fall test, boosted pentrometer test, and an in-situ heat transfer experiment will be designed. These tests are precursor to determining the feasibility of the actual subseabeded disposal. These efforts will lead to the completion in FY 1991 of the assessment of this disposal concept's feasibility.

Supporting Studies

The Supporting Studies task includes three main areas of effort: international program support, special technical reviews by prestigious scientific groups, and independent assessment of programmatic and institutional issues. The thrust of these efforts is to assure mutually beneficial cooperation, to provide an independent assessment of the technical adequacy of the program, and to evaluate potential alternatives which could improve the cost, schedule or technical aspects of the Commercial Waste Management programs. During FY 1984 the International program efforts will support international, bilateral and multilateral agreements. Summary reports will be prepared on the various international programs of the various countries emphasizing the status and planning of international waste management activities. International cooperation on experimental projects and exchange of information provide the fundamental basis for many other countries to resolve the pressing issue of disposal of Nuclear Waste. The information exchange contributes to the development of an international consensus on the adequacy and safety of geologic disposal of Nuclear Waste.

Also, in FY 1984, support of special technical reviews by the National Academy of Sciences will continue. Efforts will also continue on independent assessment of technical and programmatic issues related to the integration and conduct of the Waste Management and Fuel Cycle activities.

Test and Evaluation Facility

With regard to the Test and Evaluation Facility, the Department is currently evaluating the role, benefits and costs of the TEF and whether or not to collocate it at the repository site. As stated earlier, the Act requires the Department to present to Congress within one year of enactment its recommendations regarding the location of the TEF. The Department has initiated an evaluation of the role and benefits of the TEF with respect to its timeliness and its capability to provide additional information to resolve generic and site specific technical issues in engineering and siting via in-situ tests using up a 100 canisters of high-level waste. We are currently evaluating the advantages and disadvantages of collocation versus noncollocation.

Monitored Retrievable Storage

Establishment of the capability to deploy a Monitored Retrievable Storage system is a prudent addition to the overall nuclear waste strategy. It would allow the Government to guarantee acceptance of spent fuel and high level waste on a fixed schedule in the event there are unanticipated delays in the geologic repository program.

DOE is preparing a report to Congress describing the research and development activities necessary to develop the MRS proposal. This report will be submitted to Congress July 7, 1983. By mid-1985, DOE will submit to Congress a proposal to authorize construction of one or more MRS facilities.

These will be site-specific designs, with specifications and cost estimates sufficient to support Congressional authorization for construction and enable completion and operation as soon as practicable after authorization. The June 1985 submission will provide Congress detailed site-specific plans and alternatives to be considered over the same time period that Congress is considering the first repository site.

Spent Fuel Interim Storage

The Act clearly states that utilities have the primary responsibility for the interim storage of spent fuel. For utilities which are unable to provide adequate at-reactor storage capacity for spent fuel, DOE is authorized to provide interim storage for up to 1900 metric tons of spent fuel. The Nuclear Regulatory Commission is currently developing criteria to determine eligibility of utilities for Federal interim storage; and DOE is developing what will be a standardized contract and fee schedule for federal interim storage. DOE plans to enter into one-to-three cooperative programs with utilities to license and demonstrate dry storage technologies, such as storage casks.

Several generic spent fuel storage R&D activities are being conducted by DOE and will continue in FY 1984. Summaries of these activities and planned new activities are being communicated to the utilities to obtain comments and identify any new R&D needs. Generic R&D activities include investigations of fuel integrity under various storage conditions and the development and refinement of analytic tools for predicting the performance of fuel and storage components for use in licensing proceedings and as needed by the spent fuel storage technical community. DOE plans to demonstrate the use of a transportable, dry storage cask with consolidated fuel from nuclear spent fuel being shipped in two casks from West Valley to a DOE site around 1985.

We are currently reviewing the possible options for storage identified in the Act to determine specific storage options to be selected. DOE has informed Idaho and Tennesssee of feasibility studies for use of existing DOE facilities in those States for limited use in this program.

Technical Assistance to Nonnuclear Weapon States

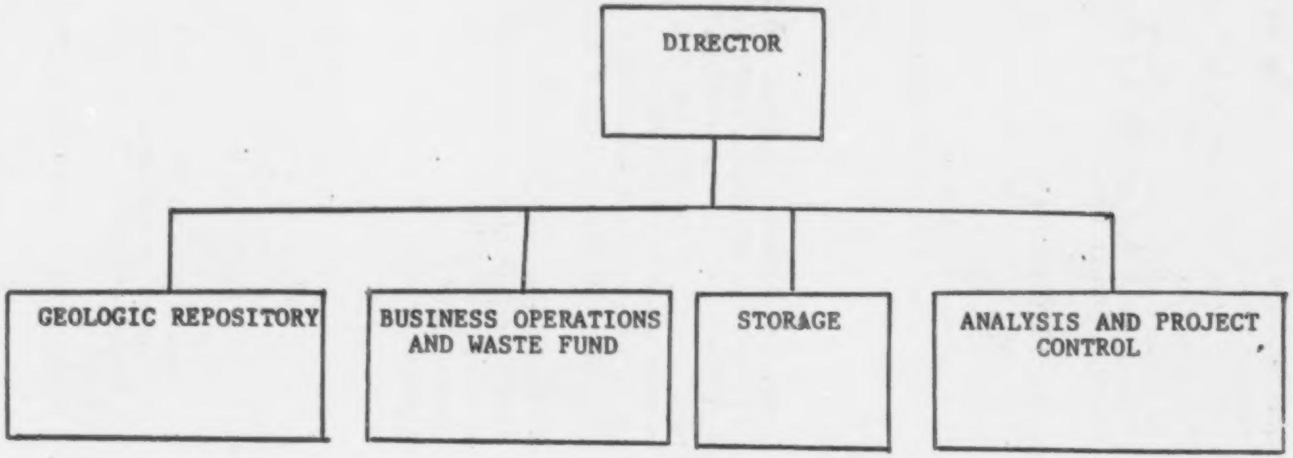
The Act stipulates that it shall be the policy of the United States to cooperate with and provide technical assistance to nonnuclear weapon states in the field of spent fuel storage and disposal. On March 30, 1983, DOE and NRC published a Joint Notice in the Federal Register announcing this policy and summarizing activities being proposed for international cooperation. This cooperation will not include the transfer of any foreign spent fuel to the United States for storage.

The Secretary of State is now to soliciting expressions of interest from the appropriate governments concerning their participation in the program. Implementation of this offer could begin in FY 1984.

In closing, Mr. Chairman, I solicit your continued support and cooperation so that the objectives of the Nuclear Waste Policy Act of 1982 can be implemented effectively and on time.

I shall be pleased to attempt to answer your questions at this time.

NUCLEAR WASTE POLICY ACT PROJECT OFFICE


DIRECTOR
GEOLOGIC REPOSITORY
BUSINESS OPERATIONS AND WASTE FUND
STORAGE
ANALYSIS AND PROJECT CONTROL

ATTACHMENT 1

Senator JOHNSTON. Thank you very much, Mr. Morgan.

In fiscal year 1984 you requested only $6.3 million for the monitored retrievable storage of nuclear waste.

Mr. MORGAN. It was $4.5 million in the original budget, and we have under consideration DOE approval to put an additional $12 million into MRS. I believe it is zero now, but we had some carryover from 1983. So we are going after $12 million for the MRS.

Senator JOHNSTON. That is for fiscal year 1984?

Mr. MORGAN. Yes.

Senator JOHNSTON. And during 1983, your statement says efforts will focus on the selection of a specific storage concepts, based as much as possible on the previous MRS study.

Can you tell me specifically what you plan to do?

Mr. MORGAN. Mr. Lawrence is in charge of my MRS program. Do you mind if I refer that question to him?

Senator JOHNSTON. Please do.

Mr. MORGAN. Thank you.

Mr. Lawrence.

Mr. LAWRENCE. Michael Lawrence. We have laid out a MRS program which, based upon the $4.1 million we had in fiscal year 1983, will allow us to actually select the concepts and identify the sites which will go into the proposal which is due to Congress in mid-1985 for the construction of one or more MRS facilities.

We are laying out criteria for the concept selection right now and we will issue those shortly. We will also be laying out criteria for site selection.

We are in the process of identifying members of an oversight committee which could be used by our Richland Operations Office which has the project management for MRS, to oversee all of the activities conducted by the program and by the contractor during this period to insure proper consideration of all the facets of the MRS concept.

But we do have——

Senator JOHNSTON. Do you have a contractor for the MRS?

Mr. LAWRENCE. We are going out for bids and a source evaluation board has been established. We are looking for a large contractor to do the detailed proposal, as called for in the act, and the associated plans and analyses required for it.

That contractor should be onboard by January 1, 1984. At that time, we would like to provide him with the actual concepts and sites to be considered for the designs required by the act and for the proposal to Congress in mid-1985.

Senator JOHNSTON. Do you have a critical path set up yet?

Mr. LAWRENCE. Yes, sir, I do.

Senator JOHNSTON. Can you furnish that to the committee?

Mr. MORGAN. Mr. Chairman, we will be happy to furnish that to the committee.

[The information follows:]

Department of Energy
Washington, D.C. 20585

Honorable J. Bennett Johnston
United States Senate
Washington, D. C. 20510

Dear Senator Johnston:

As a result of our discussions on the Monitored Retrievable Storage (MRS) proposal at the authorization hearings on May 2, I would like to provide additional information regarding our efforts to provide MRS designs specified under Section 141(b)(2)(C) of the Nuclear Waste Policy Act of 1982. Specifically, that section of the Act requires:

> "site-specific designs, specifications, and cost estimates sufficient to (i) solicit bids for the construction of the first such facility; (ii) support congressional authorization of the construction of such facility; and (iii) enable completion and operation of such facility as soon as practicable following congressional authorization of such facility;".

This will include as required in Section 141(b)(4)

> "... for the first such facility, at least 3 alternative sites and at least 5 alternative combinations of such proposed sites and facility designs ...".

We have initiated activities to provide this and we have done so in a way which we believe consistent with the Act and your remarks on the Senate floor regarding the MRS proposal on December 20, 1983.

Typically, for major design and construction projects, the Department is required to obtain Congressional authorization prior to the appropriation of funds for new plants and facilities. This authority is requested by submission of a Construction Project Data Sheet with the budget submittal. The Data Sheet contains costs estimates, schedules and facility design data based on conceptual design. Congressional authorization of the construction project is required before the engineering design (Title I and Title II) can proceed.

However, we recognize that the Waste Act requires us to go beyond these normal procedures in the MRS area, and we are proceeding based on this requirement. Specifically, the designs need to be well beyond conceptual design and completed through a preliminary design or the Title I stage to allow soliciting construction bids from a construction/engineering firm that could construct the facility. This will be done.

To enable completion and operation as soon as practicable, it is important to consider all the steps on the critical path leading to construction. Following Congressional authorization of the proposal, Nuclear Regulatory Commission (NRC) construction authorization becomes the major critical path item. It is not possible to predict with certainty the time that will be required to obtain this authorization, but NRC requirements for licensing of storage facilities have been estimated to require two and one half to three years from application to construction authorization. It is important to note that completion of what we refer to as Title II design is neither required nor customary for submission of a license application to NRC for construction authorization. In fact, designs are typically refined as a consequence of licensing review.

Thus, to satisfy the direction in Section 141(b)(2)(C), the design contractor will complete a Title I level design of at least one MRS site-specific concept and the conceptual design of four alternative concepts. A design to this level of detail will provide designs, specifications and cost estimates as directed.

We sincerely believe that our current efforts in the MRS program are fully responsive to the spirit and intent of the Act. We believe it is important that full and thorough consideration be given to the selection of the MRS concepts while the major integration contractor is being procured so that the system selected can be licensed and deployed promptly once authorized and will be fully compatible with the changing needs of the back end of the fuel cycle.

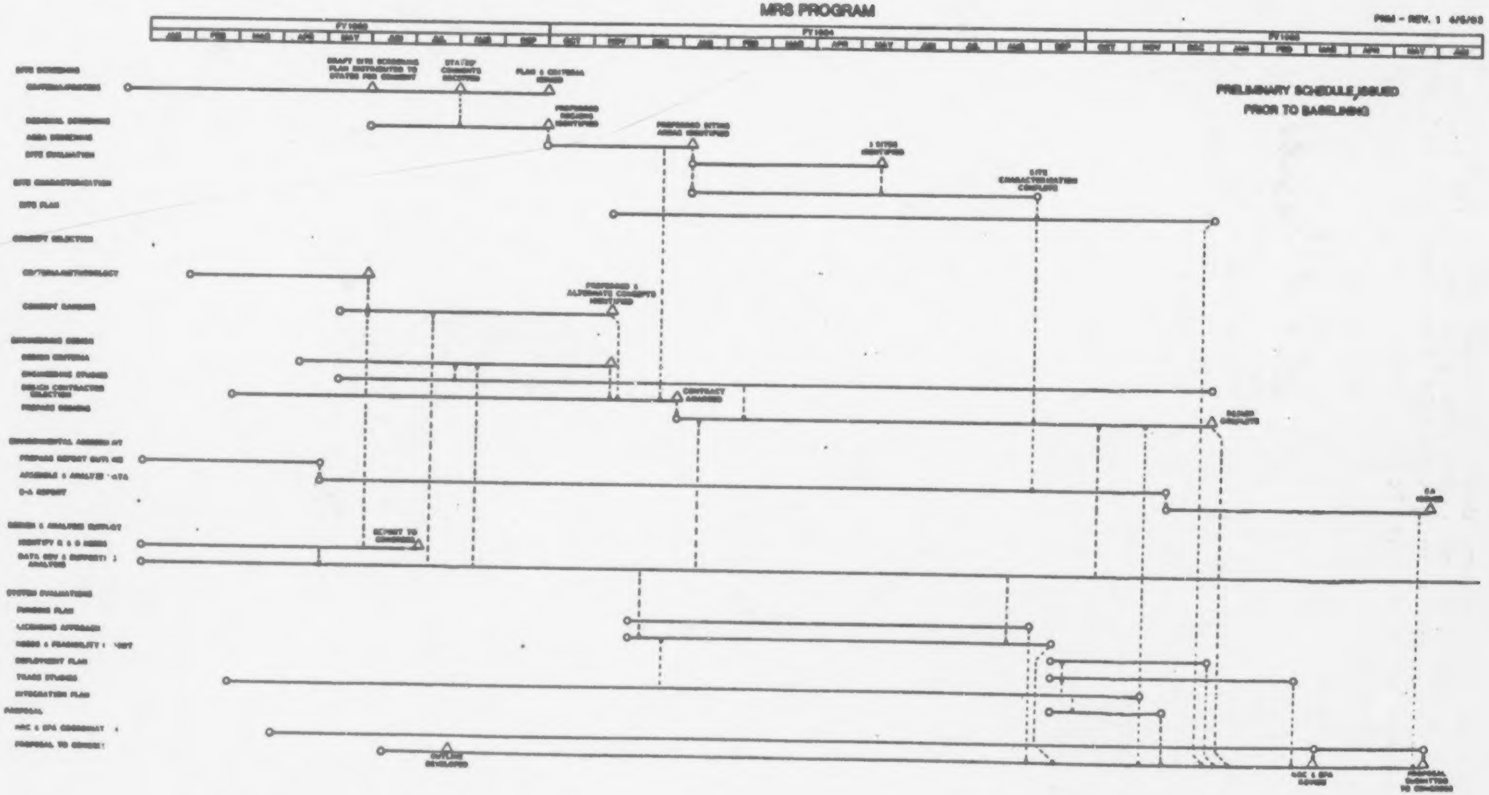
Attached is the current draft schedule for the MRS proposal. We would appreciate the opportunity to meet with you to discuss the critical path, siting schedule and other aspects of the program at your convenience.

Sincerely,

RL Morgan

Robert L. Morgan
Project Director
Nuclear Waste Policy Act
Project Office

Attachment


MRS PROGRAM
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REGIONAL SCREENING
AREA SCREENING
SITE EVALUATION
SITE CHARACTERIZATION
SITE PLAN
CONCEPT SELECTION
CRITERIA/METHODOLOGY
CONCEPT RANKING
ENGINEERING DESIGN
DESIGN CRITERIA
ENGINEERING STUDIES
DESIGN CONTRACTOR SELECTION
PREPARE DESIGNS
ENVIRONMENTAL ASSESSMENT
PREPARE REPORT OUTLINE
ASSEMBLE & ANALYZE DATA
EA REPORT
DESIGN & ANALYSES SUPPORT
IDENTIFY R & D NEEDS
DATA DEV & SUPPORTING ANALYSES
SYSTEM EVALUATIONS
FUNDING PLAN
LICENSING APPROACH
NEEDS & FEASIBILITY REPORT
DEPLOYMENT PLAN
TRADE STUDIES
INTEGRATION PLAN
PROPOSAL
NRC & EPA COMMENT
PROPOSAL TO CONGRESS
DRAFT SITE SCREENING PLAN DISTRIBUTED TO STATES FOR COMMENT
STATES' COMMENTS RECEIVED
PLAN & CRITERIA ISSUED
PREFERRED REGIONS IDENTIFIED
PREFERRED SITING AREAS IDENTIFIED
3 SITES IDENTIFIED
SITE CHARACTERIZATION COMPLETE
PREFERRED & ALTERNATE CONCEPTS IDENTIFIED
CONTRACT AWARDED
DESIGN COMPLETE
EA ISSUED
REPORT TO CONGRESS
OUTLINE DEVELOPED
NRC & EPA COMMENT
PROPOSAL SUBMITTED TO CONGRESS

Senator JOHNSTON. Thank you.

Do you believe that you will be able to meet the dates as are specified in the act for MRS?

Mr. LAWRENCE. Yes, sir.

Senator JOHNSTON. What do you have in mind at this point in terms of design; a single design or have you gotten that far yet?

Mr. LAWRENCE. Well, as you know, the proposal has to have five concepts proposed with one preferred and it also has to be based at least on three sites.

Our current thinking is to have at least two concepts and three sites to allow us to meet that requirement. However, if in selecting the concepts we find that three are very close or equal to each other, it is conceivable we could carry a third concept.

Senator JOHNSTON. All right. And then you will have one actually designed?

Mr. LAWRENCE. Sir; we will have one detailed site and concept design and then four backup designs of less quality, perhaps, than the proposed or the preferred site and concept, but also sufficient to have budget estimates.

Senator JOHNSTON. Well, the act doesn't talk about concept. The act talks about plans sufficient to go to bids with. Do you plan to have that done by the date that the act calls for it?

Mr. LAWRENCE. Sir, there has been some misunderstanding concerning that. What we plan to have in mid-1985 is an authorization sheet sufficient for Congress to consider the price and the concepts and sites under consideration, and sufficient to allow Congress to authorize that MRS proposal.

To do a detailed title II type design, insufficient time alone exists for that kind of an activity to take place. But we will be doing detailed preliminary designs on the concepts which will be equivalent to the design stage of the repository at that time.

Senator JOHNSTON. Well, now, you are just telling me that you can't do what the act calls for in my judgment. We didn't talk about concepts and things sufficient for Congress to authorize.

We had in mind, and it is very clear from the record, we had in mind sufficient plans to go to bid with. That is all through the record and every time you people come up here I tell you the same thing and every time you give us insufficient information.

I don't know what we have to do to get the message across to DOE. I just don't understand it.

Mr. MORGAN. Mr. Chairman.

Senator JOHNSTON. Yes.

Mr. MORGAN. We intend to have title I design completed. In other words, that is the full general layout and specifications.

It does not go into the nuts and bolts and the actual detailed design, but it will be ready for a contractor to submit bids and to go out on contract, but we will not have what you would call a full, total title II design.

We believe that the title I design with the full cost estimate and the design specifications is adequate to fulfill the requirements of the act and we would be happy to provide this in detail on what would be included in that title I designs.

Senator JOHNSTON. Why don't you do that? Why don't you include the detail of that?

Mr. MORGAN. Yes, sir.

Senator JOHNSTON. And along with the critical path, that may be helpful. Could you bring us up to date on the geologic storage, where you are there?

Mr. MORGAN. As you know, sir, we had a drill rig at the site at Hanford. It was ready to drill there in February. Because we do not have the final guidelines finished, we cannot have a final EA, and we deferred the drilling at the Hanford site.

As was stated earlier, on the geologic repository, we will not be nominating at least five sites as required by the act until we have the guidelines finished and a final EA for each of the nominated sites.

So we are in that process, Mr. Chairman.

Senator JOHNSTON. Getting back to MRS, quoting from the act:

> Such proposals shall include site specific designs, specifications and cost estimates sufficient to: one, solicit bids for the construction of the first such facility; two, support Congressional authorization of construction of such a facility; and three, enable completion and operation of such facility as soon as practicable, following Congressional authorization of such facility.

Now, will you in the time limits, have a site-specific design specification and cost estimates sufficient to solicit bids for the construction of the first such facility?

Mr. MORGAN. We believe that we will, Mr. Chairman, and we will show that in the time-line charts and tell you what we will have submitted at that time.

Senator JOHNSTON. Now, that is sufficient to submit bids. How can you get bids without having the nuts and bolts that you are describing?

Mr. MORGAN. The detailed design for construction, the title II design, is normally considered a construction cost and a construction item. So we were under the impression that the title I design, which is the full cost and estimate specifications, is adequate where you go out and have an architectural engineering firm—an AE—do all the detailed design and that would be a construction type of authorization.

Senator JOHNSTON. I am not familiar with the terms title I and title II. Where do those come from?

Mr. MORGAN. They are the normal terms used in construction. The first thing you do is look at a conceptual design. You are looking at concepts, or drawings and various layouts.

Then you go into title I which is a site- or concept-specific design where you can lay out major pieces of equipment—drawing plans, layout specifics—upon which you can base your cost estimate, your support for authorization by Congress for construction. That is what we intend to do in this act, sir.

Senator JOHNSTON. It says something more than that. It says solicit bids for the construction. Now, will you have these plans where you can take them, put them on the street and get a bid where somebody will put up a performance bond and agree to build what you have there without the nuts and bolts built in?

Mr. MORGAN. No, sir. We would not be able to do that. We would be able to go out and get a fixed price contract probably for the design or the AE work and we would be capable of starting site preparation at that point because we would have the foundation layout.

We could initially start out with site excavation and that type of activity with what would be in the title I process.

Senator **Johnston**. Would you agree that the language "solicits bids for construction of the first such facilities" means what it says, don't you?

Mr. **Morgan**. Yes, sir.

Senator **Johnston**. Does your statement here say you can't comply with the—I just don't understand. Here for the first time we hear you say you can't comply with the law and nobody has been informed of that. It just kind of quietly slipped.

Each time you have been up here we have asked you and you say you can comply, "Yes, we're working."

Mr. **Morgan**. Mr. Chairman, I would like to present for the record, if I may, the time line, the critical path of what we intend to do and what will be in that title I package that we would propose to give you and I would like to submit that to you at a later point if I may, Mr. Chairman.[1]

Senator **Johnston**. Well, I certainly appreciate that, but we've got a requirement of the law and you are charged with meeting that requirement and now you tell us in answer to a question that you can't meet the requirement.

You haven't informed anybody of that.

Mr. **Morgan**. Mr. Chairman, I said that I believed that we would be meeting the law if we did submit at that time the title I design and cost estimates.

And we believe that that is an adequate document that you could go out and start, quote, "the site activities" which could be the site preparation excavation.

Senator **Johnston**. That is not what the law says.

Mr. **Morgan**. And also do the AE contract.

Senator **Johnston**. What steps is DOE taking to inform States about the MRS program and potential sites for MRS facilities?

Mr. **Lawrence**. Once approved within DOE, the site selection criteria will be sent to the States for their review and comments so that we can factor in their ideas and concerns prior to finalizing those criteria in midsummer.

Senator **Johnston**. Are you going to conduct the MRS site search parallel with efforts to design the facility?

Mr. **Lawrence**. No, sir. We need to have site information prior to the actual design so we intend to have three possible sites identified early in 1984 and that will be just when the design activities are started.

So they have to preceed them.

Senator **Johnston**. There are some characteristics of the site that dictate the design?

Mr. **Lawrence**. There could be. MRS in general is not very site-demanding. But we feel we do need to have some information on the site, depends upon the concept selected. How much information is necessary.

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[1] See previous information submitted by Mr. Morgan.

Senator JOHNSON. Do you have a time for submission of a nomination of the Director of Office of Nuclear Waste Management?

Mr. MORGAN. No, sir, I do not.

Senator JOHNSTON. Will the administration consult with the committee prior to the submittal of the nomination?

Mr. MORGAN. I do not know, sir.

Senator JOHNSTON. Do you know what the criteria are being used in the search for the candidates?

Mr. MORGAN. No, sir, I do not. I have not participated in that, Mr. Chairman. I am not a schedule C or Presidential appointee and I believe it would be inappropriate for me to do so.

Senator JOHNSTON. I have some questions in writing which I would like to submit and we will look forward to receiving that, the critical path description. But I would invite your attention to the Nuclear Waste Policy Act and particularly those provisions that deal with what the proposal shall include.

If it cannot be done, then I think we should find out how much additional time it takes to do what the law requires. We slipped that time back further—frankly it appeared to me from the inaction of the Department of Energy that it would not be done.

There was almost no money requested, very little activity; talk about concepts and discussions and searches and all of that. It just didn't seem that we were going to be able to do it.

I am not even sure whether we are going to be able to do what is described today, but I do look forward to seeing what it is you had in mind and would also like to find out how much time would be necessary to do what the law actually requires.

Mr. MORGAN. Yes, sir.

Senator JOHNSTON. OK.

Thank you very much. We now have a panel consisting of Mr. John Davis, Director of the Office of Nuclear Material, Safety, and Safeguards of the Nuclear Regulary Commission; Mr. James F. Devine, Assistant Director for Engineering Geology at the U.S. Geological Service, accompanied by George Dinwiddie, Coordinator of the High Level Waste Program; and Mr. Eugene H. Rosebloom, Deputy Chief of Radiation and Waste Program.

We also have as part of the panel Mr. Glen L. Sjoblom, Director of the Office of Radiation Programs of the EPA.

STATEMENT OF JOHN DAVIS, DIRECTOR, OFFICE OF NUCLEAR MATERIAL, SAFETY, AND SAFEGUARDS, NUCLEAR REGULATORY COMMISSION

Mr. DAVIS. Mr. Chairman, it is a privilege to appear today to review the NRC's activities relating to the Nuclear Waste Policy Act of 1982. I will briefly summarize NRC activities today under the Nuclear Waste Policy Act, and for your reference, however, I am also providing section by section analysis identifying the specific actions NRC is required to take under the act and what we have done so far.

It should be noted from the start that the vast majority of actions required under the Nuclear Waste Policy Act are to be performed by DOE, and the Commission's statutory role is to provide an independent determination that DOE is carrying out its responsibilities in a manner that will protect the public health and safety and environment.

The direct consequence of this relationship is that NRC must, for the most part, develop its plan to be responsive to DOE's lead and must therefore tailor its programs to DOE's plans and schedules.

For this reason, an NRC effort to develop close communications with DOE's planning staff was one of the first actions taken by NRC to implement the act.

Any major change in the DOE program schedule for site characterization, for example, could alter NRC's schedules accordingly.

The NRC has two principal roles to perform in order to accomplish those actions mandated by the act. First, the act assigns the NRC primary responsibility for certain independent actions relating to rulemaking.

For example, the act provides that the NRC must promulgate technical requirements for licensing these geological repository for disposal of radioactive waste or spent fuel that would conform to the final EPA high level waste standards.

Second, as a part of its licensing activities, the NRC must also work jointly with DOE. For these DOE activities, NRC cannot take unilateral action but must work closely with DOE on the development of its planning and scheduling activities to accomplish those portions of the Nuclear Waste Policy Act for which DOE has the primary responsibility.

Again, examples of these types of activites include NRC's review and concurrence in the repository siting guidelines, and NRC's coordination with DOE on the development of DOE's mission plan.

For these kinds of activities, NRC has directed its staff to assess the impacts of the Nuclear Waste Policy Act from NRC's budget and resources and to work with DOE in implementing its plans and schedules.

The staff is currently developing estimates of what additional resources, both people and funds, will be needed by the NRC to meet the requirements of the NWPA.

The estimates have not been presented to nor therefore reviewed by the Commission. As soon as the Commission has approved them, they will be provided to the Congress.

We have also established and maintained close communications with Mr. Morgan who directs the DOE's implementation program for the act. We believe that these actions will assure that DOE is aware of the Commission's requirements in the area where the NRC must consult, review or concur on DOE action.

We believe they will also insure that important issues are raised at the DOE management level and resolved early so that they are not taken up at a time when they can be disruptive and lead to a delay in DOE's schedule.

We plan to continue the extensive coordination between NRC and DOE and the development of the DOE mission plant and project decision schedule to assure that there will be no unnecessary duplication of efforts in the implementation of the act.

In sum, barring any significant modifications in the place of DOE's program and assuming availability of adequate NRC resources, NRC has found no reason so far to believe that there will be major delays in the NRC implementation of the act in the foreseeable future.

NRC has placed high priority on meeting its statutory commitments. The Commission has every intention of working toward the timely implementation of the national program in accordance with the mandate of the Nuclear Waste Policy Act.

I would be privileged to answer any questions at this time.

[The prepared statement of Mr. Davis follows:]

TESTIMONY
ON THE
NUCLEAR REGULATORY COMMISSION
ON
ACTIVITIES RELATING TO THE NUCLEAR WASTE POLICY ACT

BEFORE THE
SUBCOMMITTEE
ON
ENERGY RESEARCH AND DEVELOPMENT
SENATE COMMITTEE
ON
ENERGY AND NATURAL RESOURCES

MAY 2, 1982

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE,

IT IS A PRIVILEGE TO APPEAR TODAY TO REVIEW NRC'S ACTIVITIES RELATING TO THE NUCLEAR WASTE POLICY ACT OF 1982. CONGRESS HAS PROVIDED A CLEAR AND AUTHORITATIVE DIRECTION TO THE NATIONAL HIGH-LEVEL WASTE MANAGEMENT PROGRAM WHICH SHOULD PERMIT THE BASIC ELEMENTS OF THE COMMISSION'S REGULATORY PROGRAM FOR SPENT FUEL AND HIGH-LEVEL WASTE DISPOSAL TO BE IMPLEMENTED.

I WILL BRIEFLY SUMMARIZE NRC ACTIVITIES TO DATE UNDER THE NUCLEAR WASTE POLICY ACT. FOR YOUR REFERENCE, HOWEVER, I AM ALSO PROVIDING A SECTION-BY-SECTION ANALYSIS IDENTIFYING THE SPECIFIC ACTIONS NRC IS REQUIRED TO TAKE UNDER THE ACT, AND WHAT WE HAVE DONE SO FAR.

IT SHOULD BE NOTED FROM THE START THAT THE VAST MAJORITY OF ACTIONS REQUIRED UNDER NWPA ARE TO BE PERFORMED BY DOE, AND THE COMMISSION'S STATUTORY ROLE IS TO PROVIDE AN INDEPENDENT DETERMINATION THAT DOE IS CARRYING OUT ITS RESPONSIBILITIES IN A MANNER THAT WILL PROTECT THE PUBLIC HEALTH AND SAFETY AND THE ENVIRONMENT. THE DIRECT CONSEQUENCE OF THIS RELATIONSHIP IS THAT NRC MUST, FOR THE MOST PART, DEVELOP ITS PLANS TO BE RESPONSIVE TO DOE'S LEAD, AND MUST, THEREFORE, TAILOR ITS PROGRAMS TO DOE'S PLANS AND SCHEDULES. FOR THIS REASON, AN NRC EFFORT TO DEVELOP CLOSE COMMUNICATION WITH DOE'S PLANNING STAFF WAS ONE OF THE FIRST ACTIONS TAKEN BY NRC TO IMPLEMENT THE ACT. ANY MAJOR CHANGE IN THE DOE PROGRAM SCHEDULE FOR SITE CHARACTERIZATION, FOR EXAMPLE, COULD ALTER NRC SCHEDULES ACCORDINGLY.

THE NRC HAS TWO PRINCIPAL ROLES TO PERFORM IN ORDER TO ACCOMPLISH THOSE ACTIONS MANDATED BY NWPA.

FIRST, THE ACT ASSIGNS THE NRC PRIMARY RESPONSIBILITY FOR CERTAIN INDEPENDENT ACTIONS RELATING TO RULEMAKING. FOR EXAMPLE, THE ACT PROVIDES THAT NRC:

- PROMULGATE TECHNICAL REQUIREMENTS AND CRITERIA FOR LICENSING A GEOLOGIC REPOSITORY FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE OR SPENT FUEL THAT WILL CONFORM TO THE FINAL EPA HIGH-LEVEL WASTE STANDARDS. [SECTION 121(B)]

- DEVELOP SPECIAL PROCEDURES FOR HEARINGS ON CERTAIN APPLICATIONS FOR LICENSES FOR FACILITY EXPANSIONS OF SPENT FUEL STORAGE CAPACITY AND TRANSSHIPMENT OF SPENT FUEL. [SECTION 134]

- PROPOSE PROCEDURES AND CRITERIA FOR MAKING THE DETERMINATION THAT ONSITE STORAGE CANNOT REASONABLY BE PROVIDED AT A REACTOR AND THAT THE PERSON OWNING AND OPERATING THE REACTOR IS DILIGENTLY PURSUING LICENSED ALTERNATIVES TO THE USE OF FEDERAL STORAGE CAPACITY. [SECTIONS 135(B) AND 135(G)]

  AND

- o PROMULGATE REGULATIONS OR OTHER SUITABLE COMMISSION GUIDANCE FOR THE TRAINING AND QUALIFICATIONS OF CIVILIAN NUCLEAR POWER PLANT PERSONNEL. [SECTION 306]

WE HAVE JUST COMPLETED ACTION ON THE ON-SITE STORAGE CAPACITY DETERMINATION AND WE ARE ON SCHEDULE WITH OUR OTHER RULEMAKING ACTIVITIES. WHILE THE ACT REQUIRES NRC TO PROMULGATE ITS TECHNICAL CRITERIA FOR LICENSING REPOSITORIES BY JANUARY 1, 1984, WE ANTICIPATE THAT THEY WILL BE PROMULGATED IN THE NEAR FUTURE.

SECONDLY, AS PART OF ITS LICENSING ACTIVITIES, THE NRC MUST ALSO WORK JOINTLY WITH DOE. FOR THESE DOE ACTIVITIES, NRC CANNOT TAKE UNILATERAL ACTION, BUT MUST WORK CLOSELY WITH DOE ON THE DEVELOPMENT OF ITS PLANNING AND SCHEDULING ACTIVITIES TO ACCOMPLISH THOSE PORTIONS OF THE NWPA FOR WHICH DOE HAS THE PRIMARY RESPONSIBILITY. AGAIN, EXAMPLES OF THESE TYPES OF ACTIVITIES INCLUDE:

- o NRC'S REVIEW AND CONCURRENCE IN THE REPOSITORY SITING GUIDELINES TO BE PROMULGATED BY DOE. [SECTION 112(A)]

- o NRC'S COORDINATION WITH DOE ON THE DEVELOPMENT OF DOE'S MISSION PLAN [SECTION 301(B)] AND DOE'S PROJECT DECISION SCHEDULE [SECTION 114(E)].

- o NRC'S REVIEW AND COMMENT ON DOE'S SUBMISSION OF A SITE CHARACTERIZATION PLAN FOR EACH SITE TO BE CHARACTERIZED. [SECTION 113(B)]

- NRC'S PARTICIPATION IN A WRITTEN AGREEMENT WITH DOE ON PROCEDURES FOR T&E FACILITY INTERACTION. [SECTION 217(F)(1)]

AND

- NRC'S CONSULTATION WITH DOE ON THE DEVELOPMENT OF THE MONITORED RETRIEVABLE STORAGE PROPOSAL WHICH DOE IS REQUIRED TO SUBMIT TO CONGRESS. [SECTION 141(B)(3)]

FOR THESE KINDS OF ACTIVITIES, NRC HAS DIRECTED STAFF TO ASSESS THE IMPACTS OF THE NWPA ON NRC BUDGET AND RESOURCES, AND TO WORK WITH DOE IN DEVELOPING ITS PLANS AND SCHEDULES. THE STAFF IS CURRENTLY DEVELOPING AN ESTIMATE OF WHAT ADDITIONAL RESOURCES, BOTH PEOPLE AND FUNDS, WILL BE NEEDED BY THE NRC TO MEET THE REQUIREMENTS OF NWPA. THEY HAVE NOT BEEN PRESENTED TO NOR, THEREFORE, REVIEWED BY THE COMMISSION. AS SOON AS THE COMMISSION HAS APPROVED SUCH AN ESTIMATE, IT WILL BE PROVIDED TO THE CONGRESS. WE HAVE ALSO ESTABLISHED AND MAINTAINED CLOSE COMMUNICATIONS WITH MR. ROBERT MORGAN, WHO DIRECTS DOE'S IMPLEMENTATION PROGRAM FOR NWPA.

WE BELIEVE THESE ACTIONS WILL ASSURE THAT DOE IS AWARE OF THE COMMISSION'S REQUIREMENTS IN AREAS WHERE NRC MUST CONSULT, REVIEW, OR CONCUR ON DOE'S ACTIONS. WE BELIEVE THEY WILL ALSO ASSURE THAT IMPORTANT ISSUES ARE RAISED TO THE DOE MANAGEMENT LEVEL AND RESOLVED EARLY SO THAT THEY ARE NOT TAKEN UP AT A TIME WHEN THEY CAN BE DISRUPTIVE AND LEAD TO A DELAY IN DOE'S SCHEDULE. WE PLAN TO CONTINUE THE EXTENSIVE

COOPERATION AND COORDINATION BETWEEN NRC AND DOE IN THE DEVELOPMENT OF THE DOE MISSION PLAN AND PROJECT DECISION SCHEDULE TO ASSURE THAT THERE WILL BE NO UNNECESSARY DUPLICATION OF EFFORT IN THE IMPLEMENTATION OF THE ACT.

IN SUMMARY, BARRING ANY SUCH SIGNIFICANT MODIFICATIONS IN THE PACE OF DOE'S PROGRAM AND ASSUMING AVAILABILITY OF ADEQUATE NRC RESOURCES, NRC HAS FOUND NO REASON SO FAR TO BELIEVE THAT THERE WILL BE MAJOR DELAYS IN THE IMPLEMENTATION OF NWPA FOR THE FORESEEABLE FUTURE. NRC HAS PLACED A HIGH PRIORITY ON MEETING ITS STATUTORY COMMITMENTS. THE COMMISSION HAS EVERY INTENTION OF WORKING TOWARDS THE TIMELY IMPLEMENTATION OF TH NATIONAL HIGH-LEVEL WASTE PROGRAM IN ACCORDANCE WITH THE MANDATE OF NWPA. I HOPE THIS SUMMARY OF NRC'S CURRENT POSITION ON IMPLEMENTATION OF THE WASTE ACT HAS BEEN HELPFUL. I WOULD BE PRIVILEGED TO ANSWER ANY QUESTIONS YOU MAY HAVE.

INSERT FOR THE RECORD
SECTION-BY-SECTION ANALYSIS
OF NRC'S ROLE UNDER THE
NUCLEAR WASTE POLICY ACT OF 1982

BEFORE THE
SUBCOMMITTEE
ON
ENERGY RESEARCH AND DEVELOPMENT
SENATE COMMITTEE
ON
ENERGY AND NATURAL RESOURCES

MAY 2, 1982

NRC ROLE UNDER THE
NUCLEAR WASTE POLICY ACT OF 1982

(All dates specified by the act are keyed to enactment date of January 7, 1983. Dates in parenthesis represent one year extensions permitted by Act.)

I. NRC's Role In Repository Development Program

	Provision	Specific Dates	NRC Role
1.	Siting Guidelines promulgated by DOE in which NRC concurs. Section 112(a).	7/6/83	NRC must concur in the DOE siting guidelines. Actions That Have Been Taken By NRC On February 14, 1983, DOE issued draft guidelines for public review and comment, and has published the schedule for public meetings. NRC and DOE have developed a detailed schedule for completing this action. Our technical staff has reviewed the draft guidelines and submitted written comments to DOE on April 7, 1983.

	Provision	Specific Dates	NRC Role
2.	NRC technical requirements and criteria promulgated. Section 121(b).	1/1/84	NRC must issue regulations which specify the technical requirements and criteria for the repository. Actions That Have Been Taken By NRC These regulations, which have been under development by the staff for several years, have recently been submitted to the Commission for final approval and promulgation as an effective rule.
3.	EPA final high-level waste standards promulgated. Section 121(a)	1/7/84	NRC intends to comment on the draft EPA standards.
4.	Conform NRC requirements and criteria to EPA final high-level waste standards. Section 121(b)(2).	After Event 3	Depending on contents of the final EPA standard, action may may be necessary by NRC to conform NRC regulations.
5.	DOE Project Decision Schedule. Section 114(e)	None specified	NRC must coordinate with DOE on the development of the Project Decision Schedule.

	Provision	Specific Dates	NRC Role
6.	Draft Mission Plan published by DOE for comments of NRC and others. Section 301(b).	4/7/84	NRC must coordinate with DOE on the development of DOE Mission Plan. And specify, with precision, any objections to the Plan.
7.	Submission by DOE of Mission Plan to Congress. Section 301(b).	6/7/84	Following approval of the Mission Plan by Congress, NRC will, wherever necessary, conform its waste management program planning guidance to the Plan.
8.	DOE recommends to the President 3 sites for characterization for first repository. Each of the initial 5 sites nominated by DOE prior to recommendation to the President will be accompanied by an environmental assessment (EA). Section 112(b).	1/1/85	NRC staff intends to review and comment on EA's.
9.	President must evaluate the possibility of developing a repository to dispose of defense waste only. Section 8.	1/7/85	If decision is to not include defense waste in the civilian repository NRC licensing of a separate defense waste only repository is required.

	Provision	Specific Dates	NRC Role
10.	Submission by DOE of site characterization plan, waste form or package description, and conceptual repository design to NRC for review and comment. Section 113(b).	Before sinking a shaft	NRC will review & comment on DOE submission of each site to be characterized.
11.	DOE submits to the President and the public the Commission's preliminary comments concerning at-depth site characterization and waste form sufficiency for DOE construction authorization application. Section 114(a)(1)(E).	Before event 13 below	NRC must provide preliminary comments on the adequacy of the at-depth site characterization and waste form sufficiency for DOE construction authorization application.
12.	The DOE Final Environmental Impact Statement (EIS) on the first proposed repository must contain comments from the NRC concerning the DOE draft EIS. Section 114(a)(1)(D).	Before event 13 below	NRC will review and comment on the DOE draft EIS.
13.	President recommends one site to Congress for construction. Section 114(a)(2)	3/31/87 (3/31/88)	None
14.	Submission of notice of disapproval by State, Section 116(b); or Indian tribe, Section 118(a)	5/30/87 (5/30/88)	None; see 15 below
15.	Congress may obtain any comments of the Commission with respect to a State/tribal disapproval of a site. Section 115(g).	Before event 16 below	The NRC must be cognizant of State/tribal concerns to be in a position to provide knowledgeable comments to Congress.

	Provision	Specific Dates	NRC Role
16.	State disapproval will take effect unless both Houses of Congress pass resolution of approval. (90 calendar days of continuous session.) Section 115(c).	About 8/87 (About 8/88)	None; see 14-15 above.
17.	Within 1 year after site disapproval, the President must recommend an alternative site for the first or a subsequent repository. Section 114(a)(3).	About 8/88 (About 8/89)	Role similar to initial site recommendation. See events 11-15, above.
18.	Secretary submits construction authorization application to NRC. Section 114(b).	About 11/87 (About 11/88)	An NRC licensing proceeding will be initiated on the construction authorization application.
19.	NRC must submit to Congress an annual status report. Section 114(c).	One year after submittal of CA and annually thereafter.	NRC will submit an annual status report on the progress of the licensing proceeding to Congress.

	Provision	Specific Dates	NRC Role
20.	Commission must issue decision on issuing construction authorization for first repository. Section 114(d)	1/1/89 or 11/90 or 11/91	3 year time period for NRC decision dictates an active program of involvement with DOE, States/tribes prior to receipt of application to identify and resolve contentious issues to the maximum extent practicable. Commission will either grant or deny authorization for DOE to begin construction of the 1st geologic repository. To meet this schedule, a relatively complete, good quality DOE application will be required.
21.	Secretary must recommend 3 sites for characterization to President for second repository site. Section 112 (b)(1)(C).	7/1/89	Same as event 8 above.
22.	President must recommend to Congress 1 site, from sites already characterized, for second repository. Section 114(a)(2)(A).	3/31/90 (3/31/91)	Same as events 10, 11 and 12, above.
23.	Submission of Construction authorization application to NRC for second repository. Section 114(a)(2).	About 11/90	NRC will initiate licensing proceeding for second repository.

Provision	Specific Dates	NRC Role
24. Commission must issue decisions on issuing construction authorization for second repository. Section 114(d)	1/1/92 or 11/93 or 11/94	3 year time period for NRC decision dictates an active program of involvement with DOE, States/tribes prior to receipt of application to identify and resolve contentious issues to the maximum extent practicable. To meet this schedule, a relatively complete, good quality DOE application will be required.

	Provision	Specific Dates	NRC Role
II.	NRC's Role In The Test and Evaluation Facility Program		
1.	DOE may issue T&E facility siting guidelines Section 213(a)	7/7/83	NRC will provide consultation to DOE on its T&E siting guidelines.
2.	NRC, DOE must conclude written agreement on procedures for T&E facility interaction Section 217(f)(1)	1/6/84	NRC must work with DOE in developing a written agreement for procedures for review, consultation, and coordination in the planning, construction and operation of the T&E facility. Such an understanding shall also establish the types reports and other information as the Commission may reasonably require to evaluate health and safety impacts of the T&E facility.
3.	NRC shall carry out a continuing analysis of the T&E activities to evaluate the adequacy of the consideration of public health and safety issues. Section 217(f)(3)(A).	None specified	NRC will carry out a continuing analysis of the activities associated with the DOE T&E facility.

	Provision	Specific Dates	NRC Role
4.	NRC required to report to the Secretary, the President, and the Congress Section 217(f)(3)(B).	As Required	NRC will report to the President, the Secretary, and the Congress as it deems appropriate pursuant to the Act.
5.	NRC must concur on decontamination and decommissioning of DOE's T&E facility Section 217(h)	5 Years After Initial Operation	NRC will evaluate DOE's decontamination and decommissioning activities, and concur, if deemed appropriate for a T&E facility not located at the site of a repository.

Provision	Specific Dates	NRC Role
III. NRC's Role for Interim Spent Fuel Storage		
1. The Secretary, the Commission, and other authorized federal officials shall each take such actions as such officials consider necessary to encourage and expedite the effective use of available storage, and necessary additional storage, at the site of each civilian nuclear power reactor. Section 132.	No specific dates	The Commission will consider which actions are necessary to implement the intent of this provision.
2. Hybrid procedures are prescribed for hearings on certain applications for licenses for facility expansions of spent fuel storage capacity and transshipments of spent fuel. Section 134.	Not specific but applicable to applications filed after 1/07/83.	Actions That Have Been Taken By NRC NRC is in the process of developing procedures for such a Hybrid hearing.

	Provision	Specific Dates	NRC Role
3.	Issuance of NRC proposed rule establishing procedures and criteria for making the determination that onsite storage cannot reasonably be provided at a reactor and that the person owning and operating the reactor is diligently pursuing licensed alternatives to the use of Federal storage capacity. Section 135(b) and Section 135(g).	4/7/83	NRC will issue a proposed rule establishing procedures and criteria for determining use of Federal storage capacity. (After public comment NRC will issue a final rule.) Actions That Have Been Taken By NRC The Commission has approved the rule for public comment.
4.	If the NRC determines that onsite storage cannot reasonably be provided at a reactor by the licensee DOE may, under certain conditions, provide not more than 1900 metric tons of capacity for storage of spent nuclear fuel from civilian power reactors. Section 135(a)	Not specific	NRC will make public health and safety determinations as to the use of any existing DOE facility for spent fuel storage and will license storage in new structures, including modular or mobile spent nuclear fuel storage equipment such as dry casks, as required under this provision of the Act.
5.	Transportation of spent nuclear fuel to a DOE storage facility shall be subject to licensing and regulation by NRC and by the Department of Transportation. Section 137(a).	Not specific	NRC is required to review DOE's applications for shipment and make licensing determinations for health and safety and safeguards.

	Provision	Specific Dates	NRC Role
6.	DOE, in providing for the transportation of spent nuclear fuel under this Act, shall utilize by contract private industry to the fullest extent possible in each aspect of such transportation. Section 137(b)	Not specific	NRC will be required to review the private contractor's application for shipment, and make licensing decisions for health and safety and safeguards. Regulations may, at a future date be modified or revised, to conform with DOE's repository program.
7.	NRC shall, by rule, establish procedures for the licensing of any technology approved by the by NRC under Section 218(a) for use at the site of any civilian nuclear power reactor. [Section 133.] Error exists in Act where reference is made in Section 133 to Section 219(a). Under Section 218(a), NRC may, by rule, approve one or more dry storage spent fuel storage technologies for use at the sites of civilian nuclear power reactors, without to the maximum extent practicable, the need for additional site-specific approvals.	Not specific	NRC, using data and information from DOE dry storage demonstration and cooperative programs, will develop regulations to approve dry technology storage at civilian nuclear power reactors without, to the maximum extent practicable, the need for additional site specific approvals by the NRC.

Provision	Specific Dates	NRC Role
IV. NRC's Role In Monitored Retrievable Storage Program		
1. DOE shall consult with the Commission and EPA and shall submit their comments on the MRS proposal to Congress. Section 141(b)(3).	06/01/85	NRC will consult with DOE on development of the MRS proposal, and provide comments to DOE for submittal of the proposal to Congress.
2. Submission by Secretary of an environmental assessment with respect to the MRS proposal to Congress. Section 141(c)(1).	06/01/85	NRC may, if it deems appropriate, comment to DOE on this environmental impact assessment (EA).
3. DOE shall file for license with NRC for MRS Section 141(d).	Subject to Congressional authorization of MRS.	NRC will develop amendments to 10 CFR Part 72 to provide the licensing framework for the MRS, if it should be authorized by Congress. If authorized NRC will review DOE's application and make the necessary licensing determinations.

Provision	Specific Dates	NRC Role
V. NRC's Role In The Low-Level Waste Management Area	(No deadlines were provided in the Act for the LLW management provisions under Section 151.)	
1. Commission authorized to establish by rule, regulation, or order such standards and instructions as it deems necessary or desirable to ensure that each LLW disposal licensee will have adequate financial arrangements for decontamination, decommissioning, site closure and reclamation of sites, structures, and equipment used in conjunction with its LLW disposal. Section 151(a)(1).		New sites are covered by existing regulations (10CFR61). NRC will review existing regulations and guidance for application at the existing commercial LLW disposal sites and for any needed changes for new sites.
2. If Commission determines that long-term maintenance or monitoring will be necessary at a LLW disposal site, Commission must ensure before termination of the license that the licensee has made adequate financial arrangements to ensure that any needed long-term maintenance or monitoring will be carried out by the person having title and custody for such site following license termination. Section 151(a)(2).		May require rulemaking by the Commission and the development of guidance for both existing and new commercial LLW disposal sites. For existing sites, analyses will be required to assess long term performance; monitoring and long term maintenance requirements; associated costs; and the program to review monitoring data to identify the need for mitigative actions.

	Provision	Specific Dates	NRC Role
3.	DOE shall have the authority to assume title and custody of LLW and the land on which such waste is disposed of, upon the request of the owner of such waste and land following termination of the license issued by the Commision for such disposal, if (1) the Commission determines that the requirements for site closure, decommissiong and decontamination have been met with pursuant to Section 151(a); (2) that such title and custody will be transferred to the DOE without cost to the Federal government; and that Federal ownership and management is necessary, or desirable to protect the public health and safety. Section 151(b).		Likely to require rulemaking/guidance to provide basis for required Commission determinations. Such rulemaking/guidance would require close coordination of DOE who appears to have independent discretion to accept sites following Commission determination.
4.	Adequate financial arrangements for long-term maintenance and monitoring, as well as decontamination and stabilization of special sites must be met in accordance with requirements established by the Commission before DOE may assume title and custody of the waste and the land on which it is disposed. Section 151(c).		Similiar to event 3, above.

Provision	Specific Dates	NRC Role
IV. NRC's Role Relating to Other Provisions In The Act		
1. Within 90 days of the enactment of the Act, DOE and NRC must publish a joint notice in the Federal Register stating that the U.S. is prepared to cooperate and provide technical assistance to non-nuclear weapon states. This joint notice is to be updated and reissued annually for 5 succeeding years. Section 223(b).	4/7/83	NRC will prepare a joint Federal Register notice and will provide technical assistance to non-nuclear weapon states pursuant to the Act and the FR notice. Actions That Have Been Taken By NRC The staff have prepared a proposed FR notice, coordinated it with DOE, and it was published in the Federal Register on March 30, 1983.

	Provision	Specific Dates	NRC Role
2.	The Commission shall not issue or renew a license to use a utilization or production facility under Section 103 or 104 of the Atomic Energy Act unless the applicant has entered into a waste disposal contract with the Secretary of Energy or the Secretary affirms in writing that the licensee is negotiating in good faith to enter into such a contract. The NRC in its discretion may require as a precondition to the issuance or renewal of a reactor license that the applicant shall have entered into an agreement with DOE for the disposal of high-level waste or spent fuel that may result from such a license. Section 302(b)(1)(B).	6/30/83	The NRC and DOE are still examining what the provisions mean and how they will be applied.
3.	DOE shall consult with the Chairman of the NRC in conducting a study of alternative approaches to managing construction and operation of all civilian waste management facilities and then DOE is to report to Congress. Section 303.	1/6/84	At the invitation of the Secretary, the Chairman will consult on the "alternative approaches" study.

	Provision	Specific Dates	NRC Role
4.	The Act requires and authorizes NRC to promulgate regulations or other suitable Commission guidance for the training and qualifications of civilian nuclear powerplant personnel. Section 306.	1/6/84	NRC will develop and promulgate regulations or other suitable guidance for training and qualifying civilian powerplant reactor personnel required to be implemented by the Act.

STATEMENT OF JAMES F. DEVINE, ASSISTANT DIRECTOR OF ENGINEERING GEOLOGY, U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Mr. **Devine**. I would also like to summarize my testimony and submit the prepared testimony for the record.

Senator **Johnston**. Yes.

Mr. **Devine**. The U.S. Geological Survey, as you know, is a scientific agency. It has a long-term involvement with the generic aspects of radioactive wastes and served as an advisor to then AEC, now NRC, ERDA, DOE and had many discussions with States.

We participated in the original YRG effort to determine rad waste policy. In 1979, we developed and received funding from Congress for an independent program to develop screening methodologies that are characterizing tools; studies on fundamental geological and hydrologic processes that pertain to rad waste; and to develop certain models for characterizing rad waste migration.

We have an expanded role with DOE as a result of the act and prior to the act. As you know, we had the lead role in characterizing the geology and hydrology of Yucca Mountain at the Nevada test site.

We have had some geologic studies in the Paradox Basin. We are involved in an in-depth review of the Hanford and salt site application—site information. And we are developiog programs which are looking at crystal and rocks and some geophysical techniques that will be applied for assessing potential sites.

The passage of the act——

Senator **Johnston**. Let me interrupt you at that point if I may, Mr. Devine. Have you done research on what is going on in Europe on geologic storage?

Mr. **Devine**. I have personally not. From my discussions with scientists, I am aware that people are following what is going on in Europe, but whether they have done research on it or not I would hesitate to say so.

Senator **Johnston**. You are aware that they have—I guess the word would be "postponed"—work on geologic storage while they proceed with various kinds of monitored retrievable storage?

Is that a fair perception?

Mr. **Devine**. I think that is fair.

Senator **Johnston**. Do they know anything that we can use with respect—on which they made their decision? Do you know why they decided that way?

Mr. **Devine**. I don't specifically, sir, but I would indicate that obviously a scientist, we can learn from what scientific information they had gathered and how it may apply to potential sites here.

But policy decisions resulting from that is a step beyond that which I wouldn't care to comment.

Senator **Johnston**. Now, the principal problem as I understand with geologic storage is the effect of heat on the medium, is it not?

Mr. **Devine**. That has a greater effect in some mediums than in others. In some media, that is a very strong effect and in others it is less.

Senator **Johnston**. In salt, it melts the salt, doesn't it.

Mr. **Devine**. It certainly could.

Senator **Johnston**. Excuse me?

Mr. **Devine**. It certainly could.

Senator **Johnston**. Won't it do it for sure?

Mr. **Devine**. Well, if you protect the salt from the material such as there is not sufficient heat transferred to the salt, it would not.

Senator **Johnston**. How can you do that?

Mr. **Devine**. Well, one by allowing the material to cool before it is placed in the salt. Another would be to provide insulation and barriers between the material and the salt.

Senator **Johnston**. What kind of barriers?

Mr. **Devine**. That is the limit of my expertise. I don't know the specifics. I have understood from discussions that is a technique that is possible and in actual practicality I cannot comment.

Senator **Johnston**. Well, when you say you have the lead role in characterizing geologic and hydrologic conditions, that is those geologic and hydrologic conditions without reference to what you are going to put in it?

Mr. **Devine**. That is correct, and that is at Yucca Mountain only.

Senator **Johnston**. Yucca Mountain only?

Mr. **Devine**. Yes, sir.

Senator **Johnston**. And that—Yucca Mountain is—what kind of a——

Mr. **Devine**. That is in tuff, T-U-F-F, tuff. It is a volcanic derivative rock.

Senator **Johnston**. Please proceed. I interrupted.

Mr. **Devine**. As a result of the passage of the act, we have increased our coordination with DOE and we recognize that the act requires—accelerates a need for site-specific information.

We are modifying and tailoring our programs to respond to those requirements, particularly in the consideration of the area of crystalline rock.

And finally, we would like to reaffirm that the U.S.G.S. is committed to participation to the fullest to assist DOE in the successful completion of a proper rad waste repository.

Senator **Johnston**. Can you tell me, Mr. Devine, why is U.S.G.S. involved in only the one site?

Mr. **Devine**. Yes, I think I can, sir. By nature, the Geological Survey is not a site-specific organization. We are primarily constituted to do regional studies and process research.

Site-specific work is normally better left to commercial organizations. But the Yucca Mountain, Nevada test site is a unique situation. We have had 30 years of intensive involvement there due to the weapons program.

Consequently, we had unique geologic and hydrologic skills that we felt would best apply by taking on the site-specific role at Yucca Mountain.

Senator **Johnston**. Now, Yucca Mountain is the mountain where they have had tests, is it not?

Mr. **Devine**. What kind of tests, is that right?

What kind of tests, sir?

Senator **Johnston**. I thought you——

Mr. **Devine**. Yucca Mountain is in the border area of the Nevada test site. Elsewhere on the test site there have been underground nuclear tests, but not in the vicinity of Yucca Mountain.

Senator JOHNSTON. Not at Yucca Mountain?

Mr. DEVINE. No, sir.

Senator JOHNSTON. You are familiar with the facilities at the Nevada test site?

Mr. DEVINE. Yes; I am.

Senator JOHNSTON. There is one area that is honeycombed with a lot of tunnels and areas, is there not?

Mr. DEVINE. There are areas where there have been extensive underground detonations and resulting cracks and construction tunnels to reach those and so forth, but that area is many miles from Yucca Mountain.

Senator JOHNSTON. Thank you. Are you finished with your statement?

Mr. DEVINE. Yes; I am.

[The prepared statement of Mr. Devine follows:]

TESTIMONY OF
JAMES F. DEVINE
ASSISTANT DIRECTOR--ENGINEERING GEOLOGY
U.S. GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
May 2, 1983

Mr. Chairman, I am pleased to have this opportunity to tell this subcommittee about the role of the U.S. Geological Survey (USGS) in the Nation's high-level nuclear waste management program, especially as it relates to the Nuclear Waste Policy Act of 1982. To provide assistance, I have with me Mr. George A. Dinwiddie and Dr. Eugene H. Roseboom, who coordinate our Bureau's nuclear waste program.

The USGS is a fact finding scientific organization with neither regulatory or development responsibilities. Our principal missions are to map the land, appraise the Nation's mineral and water resources, determine the hazards to man from natural events such as earthquakes and volcanoes, to provide the resulting information to the public, and to give objective earth-science assistance and advice to other agencies. In that light, we have always played an important supporting scientific role in the nuclear waste program.

In the 1960's and early 1970's, our activities in nuclear waste were relatively minor and entirely funded by the Atomic Energy Commission or the Energy Research and Development Administration. We assisted them in identifying and evaluating potential disposal sites in subsurface salt deposits and played a key role in suggesting the location for the Waste Isolation Pilot Plant site in New Mexico for defense wastes, and potential commercial waste repository locations within the Paradox Basin of Utah. We also had the lead activity in screening geohydrologic environments at the Nevada Test Site, leading to the selection of the Yucca Mountain location as a potential repository site.

In the late 1970's we participated in the Interagency Review Group established to develop a national policy for nuclear wastes. Since then, we have worked closely with the Department of Energy (DOE), to help them develop a scientifically sound and feasible program. We have also worked closely with the U.S. Nuclear Regulatory Commission (NRC), to advise them on the geologic and hydrologic criteria and guidelines in their pending high-level waste management rule, 10 CFR 60. In addition, we review other key documents for the NRC and make recommendations to them. We provide similar review and comments on Environmental Protection Agency documents such as their recently proposed standards rule for high-level wastes, 40 CFR 191.

In 1979, the USGS initiated an independent research program on the earth-science aspects of nuclear waste disposal, with its own appropriated monies. This was to provide an expanded research effort on some generic scientific issues as well as to enhance our ability to provide coordinated support to the DOE lead program.

This internal USGS research program has focused on the following major activities:

- Developing earth-science screening methodologies to identify environments that have geologic and hydrologic characteristics which potentially provide multiple natural barriers for the isolation of nuclear wastes.
- Developing new and better tools and techniques for characterizing subsurface geohydrologic properties important for isolating wastes.
- Investigating fundamental physical and chemical processes which control the migration of waste radionuclides in subsurface environments.
- Developing and demonstrating mathematical models which simulate complex subsurface processes and conditions to aid in the characterization and assessments of those environments.

We are currently conducting research in some aspects of all the above subject areas. For instance, next year we will complete the development and application of a prototype areal screening methodology applied to the Basin and Range Province of the Western United States, involving portions of eight states.

At the same time, our supporting role with the DOE has expanded. We currently conduct specific site and areal studies for them as well as provide a variety of review and advisory services. Our field studies for DOE include the following:

- The lead role in characterizing the geologic and hydrologic conditions of the Yucca Mountain site, and vicinity, in Nevada.
- A major part of the geologic and geophysical studies of the Paradox Basin bedded salt site in Southeastern Utah.
- An in-depth technical review of geohydrologic interpretations of potential repository sites at the Hanford Reservation, Washington, and the various sites under consideration in salt environments.

Other important USGS activities in the DOE program are:

- Critical reviews of regional geologic reports for the crystalline rock site screening program in the Eastern United States.
- Development and application of geophysical characterization techniques to potential sites.
- Independent advice and suggestions on a variety of other earth-science issues.
- Participation in a formal USGS/DOE Coordination Committee which meets quarterly.

The provisions of the Nuclear Waste Policy Act necessitate some response on our part to fully address the Nation's needs for nuclear waste disposal. As required by the Act, we are continuing to consult with the DOE in their preparation of draft waste repository siting guidelines. We have also assisted them in this process by serving as panel members at public hearings to receive comments on the guidelines. Although none of the provisions of the Act modify our role in the collection, analysis, and dissemination of earth-science information as diverse as seismic risk and ground-water availability, the Act clearly accelerates the need for site specific information. We can best respond to this need by modifying our internally-funded screening program to provide more generic earth-science information on a variety of potential geohydrologic environments as well as providing more direct assistance to the DOE mission.

As an example, we have just initiated a short-term study to evaluate the feasibility of finding suitable repository environments in subsurface granitic and related crystalline rocks buried by thick blankets of sedimentary deposits in the Eastern United States. This unique concept of disposal in buried crystalline rocks was first proposed by USGS scientists a few years ago and now might aid the DOE in identifying potential eastern site locations for a second repository.

We are also planning, with DOE, to assume an expanded role in certain aspects of the DOE site screening and characterization programs for both the first and second repositories called for in the legislation. This expanded effort is intended to help the DOE meet the demanding schedule specified in the Act.

The U.S. Geological Survey is committed to do its best in responding to its part of those challenges mandated by the Act. We will be happy to answer any additional questions the subcommittee may have regarding our role in the national program or specific earth-science questions relative to repository site selection.

Thank you. That concludes my statement.

Senator JOHNSTON. Mr. Sjoblom.

STATEMENT OF GLEN L. SJOBLOM, DIRECTOR, OFFICE OF RADIATION PROGRAMS, ENVIRONMENTAL PROTECTION AGENCY

Mr. SJOBLOM. Yes, sir.

Mr. Chairman, I am Glen Sjoblom, Director of Office of Radiation Programs at the Environmental Protection Agency.

I am pleased to have this opportunity to briefly describe EPA's role in the national high level radioactive waste program. Under the act, the EPA is charged with developing the overall framework of environmental protection standards that will govern the program. I have submitted my testimony for the record.

Section 121 of the act requires that these EPA standards be promulgated in final form by January 7 of next year. The NRC is responsible for implementing the EPA standards through its regulations and for issuing licenses for high level waste repositories.

The repositories in turn will be built, owned, and operated by the DOE. Both the DOE and the NRC have incorporated our proposed EPA standards in their site selection criteria and regulations respectively.

On December 29 of last year, the agency published its proposed environmental standards for management and disposal of spent nuclear fuel, high level and transuranic radioactive waste in the Federal Register, for public review and comment.

Today was the final day of that initial public comment period. We will have two public hearings on the proposed standards. These hearings are May 12 through 14 in Washington, and May 19 through 21 in Denver.

The rulemaking will then, after those hearings, remain open for written comments until near the end of June. This plan will allow us to obtain and incorporate any good ideas we get and still meet the schedule required by the act of having our final standards out by January 7 of next year.

We believe that it is particularly important that our standards be understood by the States within whose borders waste repositories may eventually be sited.

Proper understanding by these people is essential to the most meaningful and useful comments. Therefore, we have on invitation briefed several individual groups in the States of Utah, Texas, Wisconsin, and Minnesota and representatives of the several States—I think it was 11—that have formed a working group on radioactive waste under the auspices of the National Governors Association.

In addition to this public review of our proposed standards, the EPA has a Science Advisory Board and through a subcommittee of it, is conducting a thorough technical independent review of the analyses that my office conducted over the last several years in developing these proposed standard.

This subcommittee is holding hearings, and special meetings that are open to the public and they are announced in the Federal Register. Three meetings have been held by this subcommittee thus far.

Future meetings are being held today and tomorrow and again, tentatively on June 2-3 and July 12-13. Our proposed standards include two parts. Subpart A would limit the radiation exposure to members of the public during the operational aspects of this national program, namely the management and storage of the spent fuel or waste prior to its geological disposal.

These would be to the same levels as existing EPA standards applicable to the remaining parts of the uranium fuel cycle. Subpart B of our proposed standards will establish both quantitative long-term containment requirements as well as qualitative assurance requirements to insure that the containment requirements will be met.

Subpart B also contains the requirement to insure that appropriate analytical procedures are used to apply the containment requirements to specific disposal systems.

First of all, the containment requirements would limit the amounts of radionuclides projected to enter the environment——

Senator **Johnston**. Excuse me. Let me interrupt you there at that point, we will insert your statement at this point.

[The prepared statement of Mr. Sjoblom follows:]

STATEMENT OF
GLEN L. SJOBLOM, DIRECTOR
OFFICE OF RADIATION PROGRAMS
U.S. ENVIRONMENTAL PROTECTION AGENCY

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH
AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

May 2, 1983

Mr. Chairman and members of the Committee:

I am Glen L. Sjoblom, Director of the Office of Radiation Programs. I am pleased to have this opportunity to briefly describe EPA's role in the Nation's program for high-level radioactive waste disposal.

INTRODUCTION

Since 1976, the United States has been pursuing an intensive program to select, build, and demonstrate a disposal method for the high-level radioactive wastes produced by nuclear reactors. The Nuclear Waste Policy Act of 1982 (Public Law 97-425) assigns specific responsibilities and deadlines to the various Federal agencies involved in this national program, defines the ways in which states will interact with the program, and establishes a source of funding through a fee levied on the electricity generated by commercial nuclear power plants. The Environmental Protection Agency (EPA) is charged with developing the overall framework of environmental protection standards that will govern the program: Section 121 of the new Act requires that these EPA standards be promulgated by January 7, 1984. The Nuclear Regulatory Commission is responsible for implementing the EPA standards through its regulations (10 CFR 60) and for issuing licenses for all high-level waste repositories. The repositories, in turn, will be built, owned, and operated by the Department of Energy. The Department of Energy has incorporated the requirement to comply with these proposed EPA standards into its proposed repository siting guidelines and NRC has likewise incorporated them in its regulations.

THE RULEMAKING PROCESS

On December 29, 1982, the Agency published 40 CFR Part 191, proposed "Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," in the Federal Register for public review and comment (47 FR 58196). The initial comment period on this proposed rule ends today. We will hold two public hearings to explore information and issues raised in these responses. These hearings are scheduled for May 12-14, 1983, in Washington, D.C., and for May 19-21, 1983, in Denver. The arrangements and procedures for these hearings were recently announced in the Federal Register (48 FR 13444). The hearings are structured to ensure substantial interaction among the Agency participants and other interested participants on ways to improve the proposed standards.

The rulemaking record will remain open for written comments based on the hearings until mid-June. This plan will allow us to incorporate good ideas we receive from the public — no matter how substantial a change they might represent — and still proceed to promulgate the standards by January 7, 1984.

We believe that it is particularly important that our standards be understood by the States within whose borders waste repositories may be sited. Proper understanding by these people is essential for the most meaningful and useful comments. We believe this process will assure that the final standards will be technically adequate as well as help promote public confidence in the National program. Therefore we have, on invitation, briefed individual groups in the States of Utah, Texas, Wisconsin, and Minnesota, and representatives of the several States that have formed a working group on radioactive waste under the auspices of the National Governors Association.

In addition to this public review of the proposed 40 CFR 191, the Agency's Science Advisory Board--through a Subcommittee chaired by Dr. Herman Collier--is conducting a thorough independent review of the technical analyses supporting the proposed standards (48 FR 509). This Subcommittee is holding a series of meetings that are open to the public and are announced in the Federal Register. At each of these meetings there is an opportunity for members of the public to make relevant technical information available for consideration by the Subcommittee. Thus far three such meetings have been held. Future meetings of the Subcommittee are being held today and tomorrow and tentatively on June 2-3, and July 12-13, 1983, in Washington, D.C.

THE PROPOSED STANDARDS

Our proposed standards include two Subparts. Subpart A would limit the radiation exposure of members of the public from management and storage of spent fuel or waste, prior to disposal, to the same levels that the Agency established for the other parts of the uranium fuel cycle in 40 CFR 190. Management and storage operations for high-level wastes from national defense activities would be covered as well as those from commercial facilities. Subpart B of the proposed rule would establish both quantitative long-term containment requirements for high-level waste disposal systems and qualitative assurance requirements to ensure that these long-term containment requirements will be met. Subpart B also contains requirements to ensure that appropriate analytical procedures are used to apply the containment requirements to specific disposal systems.

The containment requirements for disposal systems would limit the amount of radioactivity projected to enter the environment for 10,000 years after disposal. We selected 10,000 years as a regulatory period by balancing two considerations. First, this period is long enough to encourage good site selection by requiring assessment of typical water pathways through geological media to the environment. On the other hand, it is short enough for the likelihood and characteristics of geologic events to be reasonably predictable. Through our assessments of performance of mined geological repositories, waste form, and canisters we determined that the projected risks from radiation to future generations from releases from high-level waste disposal systems over 10,000 years can be limited to a level that is no greater--on a generic basis--than the risks from the equivalent amount of unmined uranium ore utilized during the creation of these wastes.

The qualitative assurance requirements of Subpart B would provide seven criteria necessary for developing confidence that the long-term containment requirements will be met. These criteria require well-designed, multiple-barrier disposal systems that will not rely on active institutional controls for maintenance for more than a few hundred years, and that will not be located near potentially valuable resources that will attract human subsurface activities. The criteria would also require that future generations be provided information about the location and dangers of the wastes and an option to recover and relocate them if they need to.

As a part of my submission for the record, I have attached to my statement some additional information on the rationale we used in developing our proposed standard.

THE ROLE OF EPA's STANDARDS

Mankind has never before engineered and constructed any systems to effectively function for such extensive periods of time. Therefore, the consequences of this rulemaking cannot be examined in terms of the incremental changes to any existing practices and policies. Furthermore, because of the long time horizons involved, all of the key decisions about where and how to dispose of these wastes must utilize site specific long-term projections of overall disposal system performance. We cannot conduct experiments for thousands of years to see if we picked the right site and system. Because of this unusual context, we believe our standards must establish the comprehensive environmental protection framework for the high-level waste disposal program, and to do this our rulemaking process has been structured to answer some fundamental questions. For example:

> Have we selected an appropriate approach for choosing a limit on risks to future generations? Should we be more stringent, or less so?
>
> Are the quantitative analyses we considered adequate for their purpose? Do they support our finding that selection of protective sites should receive the most emphasis in the national program?
>
> Is the 10,000 year period that we propose to regulate too short because the wastes will be dangerous beyond that time? Or is it far too long for serious consideration? (Both opinions have been expressed.)
>
> Is it appropriate to limit the reliance that can be placed on institutional controls beyond a few hundred years? (If not, disposal systems might be quite different.)

Should we retain both the quantitative and qualitative requirements that we have proposed, or should we rely more heavily on one or the other?

These are some of the key issues that we expect and have encouraged comment on as we proceed to develop our final standards for disposal of high-level radioactive wastes. We are sure that there will be a variety of other comments as well, and we look forward to hearing a diversity of viewpoints--both on our proposed rule and on the technical analyses that support it. We believe that these National Standards have a key role to play in our collective progress towards solving this National problem and we believe that the public process in which we are involved will provide the greatest assurance of success.

ATTACHMENT FOR THE RECORD TO STATEMENT OF GLEN L. SJOBLOM

Rationale for Standards Development for Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes.

SELECTING AN APPROPRIATE LEVEL OF PROTECTION

We selected a level of protection to base the proposed containment requirements on by balancing two perspectives: (1) the degree of protection that appears to be reasonably achievable through disposal methods being pursued within the national program, and (2) comparisons of the potential residual risks from high-level waste disposal with the risks to future generations from other sources of radiation exposure. From this balancing, we came to the conclusion that--through the use of expected engineering control technology at carefully chosen disposal sites, and without substantial effects on waste management costs--mined geologic repositories could keep the long-term risks to present and future generations to levels no greater than those from equivalent amounts of unmined uranium ore. Thus, disposal of these wastes appears to be readily achievable without causing any increase in risk to future generations.

It is important to note that we did not rely on either of these two perspectives by itself in selecting the level of protection. For example, our containment requirements clearly do not require anything like "best available technology." In making our assessments of repository performance, we tended to make cautious analyses that should overestimate the long-term risks from our generic models of repositories. Even with this conservatism, our assessments indicate that long-term risks at least an order of magnitude lower than those associated with the proposed containment requirements are probably achievable without major effects on the national program.

On the other hand, we did not choose the level of protection merely by judging what risks might be "acceptable" based upon comparisons with other societal risks, or based upon the costs and benefits of the activities that produced these wastes. Approaches of this type have often been suggested to us. (Their advocates usually imply that these approaches would argue for less stringent requirements than those we have proposed.) However, no specific scheme to select an "acceptable" level of residual risk--independently of considerations of cost and achievability--has received enough support for practical application. And broad support of the environmental regulations for this activity is particularly important, because many governments, organizations, and other constituencies will be involved in the process of identifying, evaluating, and selecting sites for disposal of these wastes.

Thus, we have proposed containment requirements that should be quite straightforward to achieve through careful comparison of alternative disposal sites and engineering controls, and we hope they will be the basis for a broad consensus that such disposal will be both "safe" and "adequate." We are, of course, particularly interested in comments on this aspect of our proposal, which involves broad societal judgements as well as technical findings. However, it must be emphasized that we do not intend that our decisions about the appropriate level of protection for high-level waste disposal should set precedents for decisions about other types of waste disposal or for decisions about other environmental protection activities. (For example, we do not intend that "no increased risk to future generations" should become a basic principle of standard-setting--the technological, economic, and societal aspects surrounding each particular issue should be overriding.)

THE IMPORTANCE OF GOOD SITE SELECTION

As part of developing the containment requirements, we evaluated expected and accidental releases of radioactivity from generic models of geologic repositories in five different media. We examined the capabilities of waste cansiters, waste chemical forms, repository design, and the surrounding geologic media to prevent or delay the release of radionuclides. For accidental releases, we estimated the probabilities of events that could lead to the releases. We then estimated the long-term population risks from these releases through the use of very general models of environmental pathways and a linear, non-threshold relationship between radiation exposure and human health effects.

An important result of these performance assessments was our conclusion that the geochemical and hydrological characteristics of a disposal site were substantially more important to long-term environmental protection than the capabilities of a repository's engineering controls. (In turn, among the categories of engineering controls, waste form performance appears to be more important than canister lifetime.) Thus, we believe that careful site selection--from a broad variety of alternatives--must be a major part of the national program. And we hope these standards can help build the public confidence in the program that will be necessary for a diversity of sites to be available for evaluation. To enhance long-term environmental protection, potential sites must be identified, compared, and selected on the basis of their technical capabilities to isolate the wastes--not on political considerations or restrictions.

THE NEED FOR QUALITATIVE REQUIREMENTS

The qualitative assurance requirements are a very important part of our proposed standards. These seven criteria address and compensate for the uncertainties that necessarily accompany plans to isolate these wastes from the environment for a very long time. No matter how promising analytical projections of disposal system performance appear to be, these wastes should be disposed of in a cautious manner that reduces the likelihood of unanticipated releases. Our assurance requirements call for a prudent and "common-sense" approach to disposal that provides the necessary context for application of our containment requirements; we believe that these criteria are essential for developing the needed confidence that the long-term release limits will be met. Furthermore, we believe that the assurance requirements will substantially reduce the likelihood that individuals might inadvertently receive large exposures by intruding into the underground formations surrounding a repository.

Two basic concepts support these qualitative criteria. First, we believe that the isolation of these wastes should not depend upon active participation or sustained vigilance from future generations for very long. Therefore, wastes should be disposed of promptly rather than maintained in indefinite storage, reliance on institutional controls should be minimized, and sites with resources that might attract future exploration should be avoided. Second, we believe disposal systems should be designed with the understanding that expectations of system behavior over thousands of years may be incomplete or wrong. Thus, disposal systems should be made tolerant of potential mistakes in engineering design or site selection by using multiple, partly redundant barriers, and future generations should have the option to recover the wastes if new information indicates that some unforeseeable error was made.

Some have argued that these assurance requirements may unduly restrict the flexibility available to disposal system designers. Indeed, the concept of allowing maximum flexibility to achieve specific environmental protection goals (saying "what to do", not "how to do it") can be both effective and efficient in many situations. However, we do not believe we should rely upon it in this particular case because of the unusually large uncertainties inherent in designing disposal systems to isolate wastes for at least 10,000 years. Again, this proposed rule should not be considered as a precedent that will extend to the Agency's other regulatory activities.

Senator JOHNSTON. I just finished reading your statement and I am quite interested in a couple of items. You picked the 10,000 years as the proposed limit on the amount of radioactivity projection.

You say that through our assessment that you think at this time the high level waste disposal can be limited to a level that is no greater on a generic basis than the risk on the equivalent amount of unmined uranium ore utilized during the creation of these wastes.

That happens to be a test that at one point I put into some legislation I proposed, so I think it has some real logic behind it. But I am interested in how you got the 10,000 years.

The 10,000 years wasn't meant to be the time at which that event would happen. That is, that the radioactivity was down to the level of natural uranium, was it?

Mr. SJOBLOM. Not precisely. We balanced two factors in coming up with the 10,000-year period, over which the analyses would be required to be performed.

The first of these was that we wanted to make sure that one would need to consider in a geological setting the movement of ground waters, water within the pores and structures of any geological media that might be considered.

So that was one factor. In a timeframe shorter than 10,000 years, the movement of water might not play much part in picking the geological media.

Senator JOHNSTON. What is the theory—the period of time at which the radioactivity comes down to that of natural uranium? It is more like between 1,000 and 2,000 years, isn't it?

Mr. SJOBLOM. No. Some of the radionuclides, of course, are very long lived and will be there for beyond the 10,000 years. We did not elect the 10,000-year period on the basis of what would be there after that period.

The other factor has to do with the fact that it is possible to project geological events over such a period.

Senator JOHNSTON. Would you say that over 10,000 years it can be limited to a level that is no greater on a generic basis than the risk from the equivalent amount of unmined uranium ore? And my question is, When does that first occur?

Mr. SJOBLOM. We did not start out with that as a requirement, but in comparing the risks from a repository and the risk from ore bodies in some technical analysis that we did, we found that the risk from mined geological depositories in these assessments would turn out to be in the low end of the range of estimates we made of the risks over that same period of time that might accrue from radiation from the unmined ore body.

Senator JOHNSTON. Do you know when this event first occurs, when the level of radioactivity is no greater on a generic basis than the risk in the equivalent amount of unmined uranium ore?

Do you know when you first arrive at that condition?

Mr. SJOBLOM. No, sir. Like I said, that was not the requirement that we started out with.

Senator JOHNSTON. Because we have had testimony in the past that the line comes down at about 800 years.

Mr. SJOBLOM. You are talking about the concentration of radionuclides in the waste as a function of time compared to the concentration of radionuclides in an ore body.

Senator JOHNSTON. That's right.

Mr. SJOBLOM. While we could make estimates of when that would be, that was not the basis on which we set our standards. We actually went beyond that, sir, and estimated the risk to man that might occur from a release from the geological depository, and it was on that basis that we set our requirements.

Senator JOHNSTON. Are there additional risks?

Mr. SJOBLOM. It turned out, sir, that by comparing with the ore body, we have a fairly decent benchmark as you imply with which to judge the acceptability of our standards.

Senator JOHNSTON. I am not arguing with your standards. I am just simply trying to get in my mind that what you are doing is making your rules stricter, making your safety standards higher than that for a natural ore body.

Mr. SJOBLOM. I would say it would probably be more proper to characterize them as "consistent with" so that one could look at it from the point of view of future generations. We would not be passing on any greater risk to future generations than already exists from the radiation risks due to the ore had it never been mined.

Senator JOHNSTON. Well, yes, I understand that, but 10,000 years is not necessary, as I understand your testimony, to get the radioactivity down to that of a natural ore body, only about maybe 1,000 years.

So we are making our standards so that they go for 10,000 years which would indicate to me that it is stricter than that for a natural ore body. Maybe it ought to be, but is that true?

Mr. SJOBLOM. No. I would say it is comparable rather than stricter.

Senator JOHNSTON. All right.

So who is it in DOE that makes the judgment—this is to all of the panel—about the effect of waste heat on this geologic formation? Who puts it all together?

Mr. Devine, you do the U.S.G.S. work on one site and NRC studies safety and EPA is also studying safety. Who is it that looks at the effect of waste heat and the whole thing on a body so that you can compare the different sites and decide which is the best site?

Who is in charge of that responsibility?

Mr. SJOBLOM. I would say that since most of the analytical work is being done by the Department of Energy, then one parameter like the effect of heat on a strata will certainly be well within the purview of the DOE.

However, Mr. Davis obviously and his agency would be doing a lot of work to make sure that the Department of Energy carried it out in the proper manner.

Senator JOHNSTON. So that is the DOE that does that?

Mr. SJOBLOM. Right, sir.

Mr. DAVIS. Right.

Senator JOHNSTON. Thank you. Mr. Chairman.

The CHAIRMAN [Senator McClure presiding]. First, Senator Johnston, let me thank you for picking up and chairing today's session.

Without your leadership and interest, we wouldn't have gotten the bill passed.

I am very grateful to you both for that help and for your help this morning. It was necessary for me to chair the Republican conference. We were trying to get something done with respect to the budget submission of the Senate, or I would have been here at the beginning of these hearings.

As I recall from my visit to the Nevada test site and the geologic storage experiments that are underway there, the spent fuel rods have about 600 watts thermal energy.

Is that about right, about the time they arrive at that site after being stored in the pool for a number of years or some time?

Mr. DEVINE. Sir, you may be referring to the climax demonstration site and I cannot speak to the specifics of that site. That is a different area than the Nevada test site than the Yucca Mountain site.

I am sorry. I can't answer that question.

The CHAIRMAN. All right. The reason I mention that is that a lot of people believe that what we are putting into storage is kind of a seething, boiling cauldron of radioactive waste and very, very hazardous.

If they get it down to the point where they understand it is comparable to the wattage that they may have in their kitchen, that maybe they are less afraid—perhaps can put it into the context of the degree of risk to which they would be exposed.

Those rods surely have been out of the reactor for awhile and they have been in the pool storage for awhile. They cooled down both physically, thermally, and chemically so that they are not nearly—that isn't to say they are exactly the same state when they go into that storage as they were when they came out of the reactor.

But nevertheless they are in a status which is something which we can at least say to the people with some degree of assurance we know how to handle.

I understand prior to coming here that the questions have dealt with particularly a time specified in the act and I understand you indicate that you think you cannot meet the first of those—the construction bid date, is that correct?

Mr. SJOBLOM. Senator, I think it might be worthwhile to point out that the Department of Energy is not represented on this panel, and Mr. Morgan was here earlier and I think that question is one which Mr. Johnston——

The CHAIRMAN. But you are looking at a timeline in your own work——

Mr. SJOBLOM. Yes.

The CHAIRMAN [continuing]. With respect to the other matters that are required within the act, and we know certainly that the time frame that we said in the bill was extremely demanding.

We know too that it took us a little longer to get it through the Congress than when we planned when we set the original dates, which is not a way of inviting people to miss those dates that are set.

It is a way of recognizing we may have set a very, very difficult standard to be achieved. We want to be realistic in those dates. We want—it is perhaps more important to get the job done well than it is to get it done be a specific date.

Again, I don't say that to invite people to miss those dates because I think they are still very important in terms of public perceptions. Even if we set them erroneously, it is dangerous to miss them without stimulating the public's belief that here we go again: promises are made that are not being kept, or here we go again, the scientists can't do what they have been telling us that they could do.

Having said that as a background, do you believe that the dates that are set within the statute are reasonably achievable? When I say reasonably achievable, in the context of the period of delay that we have heard testimony and are set forth in the statements made to us today?

Mr. SJOBLOM. With regard to the requirements that EPA promulgate its standard by January 7 of next year, I believe that is a reasonable timeframe, yes, sir.

Mr. DAVIS. With regard to NRC, in our interface with DOE, we are somewhat captive to DOE's schedule and assuming we have adequate resources and assuming that we do not uncover or DOE does not uncover something totally unexpected from the safety or adequacy standpoint, we believe that NRC implementation can meet these dates.

I will agree, however, they are very tight schedules.

The CHAIRMAN. The Supreme Court decision with respect to what nuclear waste legislation means or does not mean in the context of State legislation, with respect to the economic reactors, timeframes become even more important to us, although that Supreme Court decision was not totally unexpected.

Mr. Davis, the Senate had a great deal of interest in the interim spent fuels storage program and since Senator Johnston has been conducting this hearing up to this point, I suspect he has asked questions about that already.

In particular, I am concerned that the NRC quickly provide its hybrid procedures for hearings on applications for facility expansions for spent fuel storage.

Could you comment on the Commission's progress in that area?

Mr. DAVIS. All right, sir. We, as you know, sir, we do have a rule in place for the licensing of interim storage. We have before us now at least one application from a utility for interim storage and three applications for dry cask storage topical reports which in effect once we have improved an atopical report, that cask can be plugged in to size-specific applications.

It will take us about a year to a year and a half to process these applications which are before us now. This licensing process will consider not only approval of these specific applications, but also serve as a learning process of how to formulate generic licensing requirements for part 72.

So we are about a year away from coming to tight grips with that right now.

The CHAIRMAN. The act provided that—of course that the NRC in their procedures, they do this in a manner so as to minimize the need for additional site-specific approvals and hence the question about the generic.

Mr. DAVIS. Right, sir. That is what we intended to do. Specifically we see this as applicable at reactor sites.

The CHAIRMAN. Obviously the NRC is being asked to take on a significant amount of new work, as you mentioned, and have properly and carefully said if we have sufficient resources we can do certain things.

I would appreciate it if you would make available to us some estimate of your resource needs as they are determined by the Commission. I understand there is some doubt yet as to the exact amount of resources you may require.

Mr. DAVIS. We will be getting estimates to the Commission quite promptly and as soon as they have completed their review, we will send them directly to the Congress.

The CHAIRMAN. I would appreciate that because there are some opportunities for us to expedite the approval of those resources here. Within the Congress they may be a little bit ahead of the normal budgetary cycle.

Mr. Davis. We would appreciate that, sir, yes.

The CHAIRMAN. Again, I recognize how stringent that schedule is and the additional work which you are going to have to do and we want to make sure that you can do it and as nearly on that schedule as we set the statute at as was possible to do.

There may be some other questions submitted in writing for response in writing for the record. We would appreciate your prompt response to those questions.

Mr. DAVIS. We would be happy to do so.

The CHAIRMAN. Thank you very much for your appearance here today. The meeting is adjourned.

[Whereupon, at 11:54 a.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX V

Answers to Additional Questions Submitted for the Record From Mr. Morgan

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Department of Energy
Washington, D.C. 20585

1254

May 31, 1983

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
  Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On May 2, 1983, Robert L. Morgan, Project Director, Nuclear Waste Policy Act Project Office, appeared before the Energy and Natural Resources Subcommittee on Energy Research and Development to discuss the Fiscal Year 1984 budget for the nuclear waste activities program.

Following the hearing, questions were submitted to Mr. Morgan for response. Enclosed are answers to those questions. A copy of the enclosed answers has been sent to the Committee.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin
    Committee Staff

Questions Submitted by the
Subcommittee on Energy Research and Development
Senate Committee on Energy and Natural Resources

Question 1:	How much money does the Administration now plan to spend on the Monitored Retrievable Storage (MRS) Program in fiscal years 1983 and 1984? Do you have plans to request supplemental funding for fiscal year 1983? If not, why not?
Answer:	The Department's FY 1983 budget includes $3.5 million plus $600,000 of unexpended FY 1982 funds for work in the MRS area. In the FY 1984 budget submission, we explained that the budget requirements to fulfill the MRS provisions of the Nuclear Waste Policy Act of 1982 (NWPA) are still being evaluated. A budget amendment for $12.0 million is being considered to enable the Department to develop the proposal required by the NWPA. The Department does not plan to request supplemental funding for FY 1983 for the MRS program. The most demanding element of the MRS proposal, from a cost and schedule viewpoint, is the development of the MRS designs specified in Section 141 (b)(2)(C).

Engineering design services from a qualified firm will have to be procured for this activity, and procurement of this scope and magnitude takes seven to nine months to place. Thus, the additional funds are not required until this contract is signed in the beginning of FY 84.

In FY 1983, the necessary systems analyses, concept evaluations, site screening activities and other supporting efforts are being performed to allow the designers to proceed immediately with their design efforts. The $4.1 million in FY 1983 is sufficient for this.

Question 2: I understand that the Department is considering yet another round of "conceptual development" for the Monitored Retrievable Storage (MRS) program. Forgive me, but this sounds like more study of abstract matters and none of the detailed engineering work that I think you should be doing. Would you please describe in detail how you intend to comply with the requirements of the Nuclear Waste Policy Act with respect to MRS? How are we going to get to the point at which the required proposal can be submitted to Congress?

Answer: The Department is not at this time considering another round of "conceptual development" for the MRS. In the past twelve years, the Department and others have studied eight alternative concepts for the storage of spent fuel and high level waste which would potentially be designed as MRS facilities. The Department is at this time identifying the specific MRS system characteristics, so that these previously studied systems can be evaluated objectively against these criteria. In this manner, the concepts best suited for the MRS application will be selected for the engineering design.

The proposal and supporting documents for construction of one or more MRS facilities will be provided to Congress on or before June 1, 1985. This submission will provide Congress detailed site-specific plans and alternatives to be considered over the same time period that Congress is considering the first repository site. These products will be developed through an integrated MRS program consisting of the following major activities:

Program Management, Integration and Systems Evaluation and Program Integration

The activities are directed toward providing overall program management and the analyses and supporting information necessary to integrate the MRS program. This includes the needs and feasibility report, the MRS funding plan, the MRS deployment strategy and the integration plan. In FY 1983, analyses are being performed to define a proposed mission and role for the MRS and the functional design requirements. In FY 1984, analyses and evaluations will be performed to develop the specific deployment strategy, funding and integration plans to be submitted with the June 1985 MRS proposal.

Siting

Siting activities are directed to screening suitable sites for an MRS facility. This is to be accomplished in a clear defensible manner that considers the site characteristics important to MRS siting and the perspectives of State and local governments and Indian Tribes. In FY 1983, an overall siting plan to include siting guidelines and provisions for interacting with State and local governments and Indian Tribes will be developed. In FY 1984, site screening and related activities will identify potentially suitable MRS sites.

Facility Design

This includes activities related to the identification, evaluation, selection and design of concepts, as well as identification of licensing requirements and issues.

The FY 1983 efforts will focus on the selection of specific storage concepts based, as much as possible, upon the previous MRS studies conducted by the Department and others. FY 1984 activities will focus on engineering design of reference and alternate concepts and sites, as well as completion of sufficient design information for specific sites, including specifications and cost estimates, to support submission of the proposal in June 1985.

Design and Analysis Support

These activities will focus on the identification of data and results needed to effectively support the other program elements. FY 1984 activities will provide the specialized information required to adequately address the prime system functions of monitoring, retrieval and, ultimately, decommissioning. Priority will be given to assuring adequacy of data to support fulfilling design, licensing and National Environmental Policy Act (NEPA) requirements.

Environmental Assessments

Environmental Assessment activities are directed at preparation of the Enviromental Assessment required by the Act to accompany the proposal to Congress. Activities will include: data review and analysis; report preparation; and a full analysis of the relative advantages and disadvantages of all five alternative design combinations of proposed sites and facility designs. In FY 1984, specific site information will be collected and comparison of the reference concepts will be initiated.

Question 3: What steps is DOE taking to inform States about the Monitored Retrievable Storage (MRS) program and potential sites for MRS facilities?

Answer: The MRS siting activities which the Department has initiated parallel those being implemented in the Geologic Repository Program. Draft siting guidelines and criteria are being developed based on the MRS functional requirements and unique features. These guidelines and criteria, along with a description of the MRS program, will be provided to the States and other known interested parties and made available to the general public for their review and comment within the next several weeks.

As the site identification process is implemented based on the guidelines, those involved states will be kept fully informed and their participation will be solicited throughout the program.

Question 4: What steps are being taken to inform States about status of waste to be stored under the Monitored Retrievable Storage (MRS) and repository approaches to the isolation of nuclear waste?

Answer: The States and the general public are informed of the status of materials from civilian nuclear activities through several mechanisms. The Department annually publishes a status report documenting the capacity and current and projected spent fuel storage requirements at each utility site. The MRS siting guidelines document will also provide the States with a brief summary of the status and projected amounts of spent fuel from commercial nuclear power operations which will need to be stored under the MRS and repository approaches. The Mission Plan will provide detailed information regarding the waste program, including proposed load strategies for facilities. The MRS R&D Needs Report, testimony and program planning documents will be available as additional sources of information through which interested parties will be informed of and have an opportunity to comment on our proposed plans and status of implementation.

The Geologic Repository Program has had and continues to have extensive interaction with States including correspondence, meetings and Public Hearings intended to cover all aspects of Civilian Nuclear Waste.

Question 5: What does monitoring consist of under your plans? That is, do you plan to actively monitor stored waste, or simply isolate the waste and retain the capability to monitor it? Explain your reasoning.

Answer: Under the current Department plans, the stored materials are to be actively monitored, that is, the critical parameters will be continuously or periodically recorded and evaluated to assure safe operation. However, the concepts under consideration all provide for passive cooling and containment not requiring any active monitoring to ensure safety.

In the MRS system design, as in any design process involving the containment of hazardous materials, design decisions are based on the requirement to assure that the containment function is being performed and the materials are adequetely isolated from the biosphere.

If systems cannot be designed or sited to assure sufficient isolation, monitoring will allow the system operators to review their confidence in the containment function. For an MRS system, the designers rely on a combination of engineered barrier and monitoring to assure sufficient isolation.

Question 6: What is being done about the shipping package for spent nuclear fuel? Is this same package to be used for storage, if not why?

Answer: There exist today both rail and truck casks licensed by NRC for shipping spent nuclear fuel. Additional casks, based upon existing or new designs will be required in the future to meet increased transportation needs.

Even though existing casks are technically capable of storing fuel, they would not be very economical because of their relative high cost and small capacity per cask. In addition, NRC licensing requirements for transport casks are markedly different, and more severe, than the licensing requirements for storage casks. Nonetheless, we recognize the considerable merits of developing a transportable storage cask and are currently in contractual negotiations leading to the development and demonstration of such a cask within the next two to three years.

Question 7: Do you plan to have a generic MRS design to fit any site? Why isn't it possible to decouple the MRS site search from design of the MRS facility?

Answer: The concepts which the Department is considering for design to be part of the MRS proposal have different degrees of site independence. It is our current belief that designs which offer siting flexibility are preferable options. If the specific concepts which best satisfy the system's functional requirements are capable of being sited at almost any location, the site search could indeed be relatively independent design activities. This would provide additional time for the Department to interact with the States and other potentially affected parties.

Question 8: Are you going to conduct the MRS site search in parallel with efforts to design the facility itself? If not, why not?

Answer: The MRS site search is being conducted in parallel to the design efforts to the maximum extent possible. The NWPA requirement for "site specific designs" necessitates that the Department develop specific site topographic, load-bearing and other data needed for the designer prior to designing approach roads, handling facilities and storage units. Thus, we are limited in the amount of parallel efforts which can be pursued.

Question 9: When does the Administration plan to submit a nomination for Director of the Office of Nuclear Waste Management? Will the administration consult with this Committee prior to submitting this nomination? What criteria are you using in your search for candidates?

Answer: It is my understanding that the Administration may submit a nomination for Director of the Office of Civilian Radioactive Waste Management soon. However, since I am a career employee, I am not involved in the selection process nor am I involved in the interactions between the Administration and the Congress concerning any forthcoming nomination.

Question 10: Nuclear Monitoring Systems and Management Corporation is a Houston-based firm with a strong interest in monitored retrievable storage of nuclear waste that predates the legislation establishing the MRS program. Has the Department evaluated the work this firm has been doing on nuclear waste isolation? What is your reaction?

Answer: The Department has been in contact with this firm and is evaluating their ideas for possible inclusion in the MRS program. The Waste Program is interested in all developments in storage technology which could potentially lead to a more efficient program. At this time, representatives of the MRS program plan to attend an upcoming demonstration of Nuclear Monitoring System and Management Corporation Storage Concept.

Question 11: In January 1983, as the Nuclear Waste Policy Act was awaiting the President's signature, Science magazine published an article in its News and Comment section entitled "The Radwaste Paradox". The conclusion of this article was that public health and safety does not require early disposal of the nuclear waste. The article included site specific discussions of the various media the Department has under consideration for geologic repositories. A number of comments in the article were attributed to U.S. Geological Survey personnel. These comments addressed the confidence geologists could reasonably be expected to have in these media and the sites now even more urgently under consideration by DOE. The comments were not reassuring.

Answer: I have read the article and I have met recently with the author. It is my understanding that when Mr. Carter was developing the article, he met with and discussed his concerns with DOE program personnel involved in the nuclear waste program.

I agree with the premise of the article that technically speaking, "you can't appreciate the problems until you get there." However, I believe Mr. Carter would agree with me that we must get there; we must provide for permanent disposal of high-level nuclear waste. I believe that we now have the framework for site selection and for the technical, political and programmatic processes which will lead to the operation of the first repository in 1998.

As I have previously stated, the Department has a commitment not to sacrifice technical quality and reliability for schedule purposes. While I believe that this country does have the technology to proceed with development of permanent waste disposal, engineering and scientific testing and site characterization activities will receive the maximum technical and public participation and review prior to site selection.

The Radwaste Paradox

Political pressures push for a speeding up of the geologic disposal program, but technical considerations may call for a slowing down

Early explorers and settlers of the Colorado Plateau, in coming to a deep bathtub-shaped valley just east of what is now the Colorado-Utah state line, were astonished at how the Dolores River, a tributary of the Colorado, cuts across the valley and through its steep walls at right angles. They called this place "Paradox Valley," and the much larger geologic province in southeastern Utah and southwestern Colorado of which the valley is a part was to become known as the Paradox Basin. As it happens, the Paradox Basin is one of the places where the U.S. Department of Energy (DOE) is looking for a site for a deep-mined repository for high-level radioactive waste. This seems appropriately symbolic because the geologic disposal problem has increasingly taken on the aspect of a political and technical conundrum, replete with real or seeming contradictions and paradoxes.

A central paradox is that, while the concept of sequestering long-lived wastes in mined repositories is attractive intuitively, the very efforts made to confirm the suitability of particular rock formations give rise to further uncertainties, at least in the early years of the site investigations. Overcoming these uncertainties, which are arising in every rock type and at virtually every site under investigation, takes time and may in some cases require the stretching out of schedules. But under the radwaste legislation approved by Congress last month (see box) the present DOE schedule for site selection and licensing could be accelerated by more than 2 years. The new law contemplates that, barring certain discretionary extensions, repository construction will start as early as 1989.

This is 6 years away and many people in Congress and the nuclear industry find it hard to understand why it should take any longer than that to find a suitable site and begin excavating a mine and getting rid of the waste. The scientific and technical questions associated with deep geologic disposal of radwaste—especially heat-generating high-level waste—are sufficiently specialized and obscure that for most people it seems that, as the saying goes, "you can't appreciate the climb until you get there."

Top DOE officials have themselves sought to push the geologic disposal program to a faster pace than the one DOE was following at the end of the Carter Administration. "I've tried to see that the schedule is accelerated," Deputy Secretary of Energy Kenneth Davis told *Science*, adding that a congressional mandate for a still faster schedule "could be helpful." In his view, it is likely that not just one but several of the sites under investigation will be usable. "I don't see a problem," he said. "My expectation is that it will be a question of which one to choose, not which one is acceptable."

Public health and safety does not require early disposal

DOE and the nuclear industry are feeling pressure from Congress and the public to demonstrate final disposal of radwaste. Public health and safety does not require early disposal; indeed, with passage of time the radioactive decay of the shorter lived fission products reduces the waste's heat and makes ultimate disposal easier. The pressure to move quickly is political and stems from the fact that, with the nuclear enterprise now in its fourth decade, it is an acute embarrassment that the waste problem has not been solved.

These circumstances seem to have produced what are in a sense two facets to the geologic disposal program. One is the difficult, time-consuming, brow-mopping research and development effort that the DOE staff people and contractors are struggling to carry out in the field. The other is the self-confident, briskly paced program that the nuclear industry and its supporters in Congress and the higher echelons of DOE see as vital to the industry's political needs and ultimate survival.

The National Waste Terminal Storage (NWTS) program, as the DOE geologic disposal effort for commercial high-level waste is known, is large and far-flung, especially compared to radwaste disposal programs abroad. In Germany, which has gone further than any other foreign country in its efforts to establish a radwaste repository, the geologic investigation has focused exclusively on one rock type, salt, and on one site, the Gorleben salt dome of Lower Saxony. By contrast, DOE, to hedge its bets and to meet the requirements of the Nuclear Regulatory Commission (NRC), is investigating multiple rock types and multiple sites. Moreover, the sinking of large exploratory shafts at three sites is a prerequisite to the filing of a repository permit application. The shafts will allow lateral entry into and testing of the rock formation at the repository horizon.

The multiplicity of sites and rock types in part reflects a political need to "spread the misery" by demonstrating that no one part of the nation will be expected to bear the entire burden of nuclear waste disposal. Taken overall, the NWTS program constitutes an enormous geologic research effort; its budget is now approaching a quarter of a billion dollars a year and is rising.

Furthermore, by virtue of political circumstances, the demands of the NRC and the National Environmental Policy Act, and DOE's own sense of technological caution, the department is committed to an elaborate program review process in which the agency not only solicits but pays for kibitzing by outsiders. The U.S. Geological Survey (USGS), for instance, has recently been brought into the program to a far greater extent than ever before. Similarly, most of the potential repository host states are becoming increasingly involved in the review of program plans and data pertaining to the investigation of sites within their boundaries; in some cases these DOE-state relationships have been going acrimoniously, in others more harmoniously, but with the exception of Nevada, all of the host states have chosen to enter into formal arrangements of one kind or another with DOE whereby they are supposed to receive project information regularly.

To find sites for the two repositories that are expected to be needed by early in the next century, investigations have been under way for some time in four different kinds of geologic formations in six places: the old basalt lava flows of the Columbia Plateau at DOE's Hanford facility in Washington; the welded tuff (another kind of volcanic rock) at the Nevada Test Site, not far from Las Vegas; bedded salt in the Paradox Basin of southeastern Utah and the Palo Duro Basin in the West Texas panhandle; and salt domes in Louisiana and Mississippi. Within a year or so field work is expected to start in the Precambrian shield granite of the upper Midwest and in the granite of the Appalachian Mountains.

The next major step in the NWTS program is to come in 1983 and early 1984 with the sinking of exploratory shafts at Hanford and the Nevada Test Site, in basalt and tuff, and at a salt site to be chosen from among the four salt locations which DOE still has under investigation. One of the three sites picked for exploratory shafts will, under the present DOE schedule (which the radwaste legislation may accelerate), be selected for a licensing application by 1988. Also, either at one of these sites or at some other, an unlicensed "Test and Evaluation Facility" for temporary storage of a few hundred waste canisters would be built and put in operation by the fall of 1989. A second repository site would be chosen in the early 1990's.

But the experience so far at the several sites suggests that the technical and political questions tend to proliferate rather than diminish as more becomes known about the geology and hydrology.

The Hanford basalt. The priority being given the Hanford basalt and the Nevada tuff has not come about because those geologic media have been known from the first to be suitable for radwaste disposal. In fact Rockwell International, the DOE contractor at Hanford, was called to account in 1981 by its Hydrology and Geology Overview Committee (a group made up largely of university-based scientists) for stating that the Hanford basalt was under study "because of the favorable geology of the site."

The committee observed: "We trust this is not a representative attitude. There is really only one solid justification for studying this site and it is the sociopolitical fact that the land is a U.S. nuclear reservation. From a hydrogeological perspective, the Columbia River Basalt Group as a whole is not well suited for a high-level waste repository. It may well be that with further data and/or careful engineering design it can be shown to be acceptable, but it cannot be stated that the 'geology is favorable.'"

The political climate for the basalt project is more or less sympathetic in the Hanford vicinity, where the people have long been familiar with things nuclear. But elsewhere in the state attitudes are reserved, to say the least. In 1980, Washington citizens voted overwhelmingly for a ballot initiative to limit or prevent nuclear waste—high as well as low level—from being shipped in from outside the state (a law that has since been declared unconstitutional). Governor John Spellman, with support from DOE, has recently established a task force to bring the basalt project under close state review.

DOE realizes that it is on its mettle to show that the basalt investigation is being conducted in a rigorously scientific manner. The participation of the USGS in this investigation has in recent months been earnestly solicited. This marks a big change from the late 1960's and early 1970's when the basalt studies were starting under ARCO, the DOE contractor at the time. The USGS scientists found ARCO so unresponsive to their suggestions and critiques that they chose to withdraw.

Now the USGS is focusing on th
hydrologic regime in the basalt, in partic
ular on the possible pathways by whic
radionuclides could be transported fro
the repository site to the Columbia Ri
er. Rockwell believes that the dischar
point is quite distant and that it wou
take 40,000 years or longer for radion
clides to reach the river, an estim
which if accepted would satisfy regu
tory criteria by a wide margin.

But the USGS has not yet review
Rockwell's data or its data-collec
methods, and remains to be convin
"We feel that the groundwater flow
tem could be discharging all along

Waste Bill Approved

Finally reaching agreement in the waning days of the 97th Congress, the House and Senate on 20 December passed legislation that is intended to bring a federal-state accommodation on radioactive waste disposal.

The main barrier to final passage was lifted when Senator James McClure (R-Idaho), chairman of the Energy and Natural Resources Committee, yielded to the threat of a filibuster on an issue deemed of critical importance by potential repository host states. Their position was that, if a repository site selected for licensing application by the Department of Energy (DOE) and the President should be unacceptable to the host state, its "veto" of the site should stand unless overridden by both houses of Congress.

Although there was substantial congressional support for this position, the bills first passed by the House and Senate had not gone that far, each body having chosen instead to give the host states a veto that would stand only if sustained by at least one house of Congress. But Senator William Proxmire, whose home state of Wisconsin contains granite formations that are of interest to DOE, was able to take advantage of the lateness of the hour by threatening to filibuster unless the state position was accepted.

McClure, as Senate manager of the legislation, chose to give in to Proxmire rather than see the legislation die, just as a previous radwaste bill had died in 1980 at the close of the 96th Congress. This broke the impasse, with the Senate agreeing by voice vote to the bill with the more liberal state veto provision. Final passage in the House was by a vote of 256 to 32.

The concession made to the potential host states should give them strong leverage in their dealings with DOE, whom some of the states (particularly Utah) have accused of failing to give them complete and timely information and of attempting to push the site selection process too rapidly.

But environmental lobbyists, citing what they perceive as important defects remaining in this long and complex piece of legislation, would have preferred to see the measure die. They found especially objectionable some procedural shortcuts on environmental review and a provision calling for DOE to present to Congress within 2½ years a site-specific proposal for a Monitored Retrievable Storage (MRS) facility for spent fuel or high-level waste. They see in the MRS the possibility that the goal of permanent disposal of radwaste might be abandoned. But nuclear industry lobbyists and DOE strongly favored passage of the legislation despite the major concession to states' rights. DOE has felt hamstrung for lack of the kind of statutorily defined federal-state "consultation and cooperation" mechanism that the legislation provides.—L.J.C.

river." John B. Robertson of the USGS told *Science*. To resolve this issue, a special review group has been established, with Rockwell, the Battelle Pacific Northwest Laboratories, and the USGS all participating, and with the Lawrence Berkeley Laboratory serving as referee.

But a variety of other questions also has been raised. For instance, fractures found in core samples suggest that the basalt is under high horizontal compressive stress. Besides complicating the design and construction of the repository, the stress might induce fractures and create new pathways for radionuclides to escape.

Now there is even a question whether the very large, 20-foot-diameter shaft needed for a repository could be constructed deep into the basalt. "At the moment, a big issue is can they in fact sink a shaft," say Harry Smedes, a respected field geologist formerly with the USGS who is now an adviser to the NWTS program leaders. "Knowing that the upper third of the formation has a lot of water-bearing beds in it, they feel that you have to drill an enormous borehole rather than use the conventional drill-and-blast, dig-it-out method where you've got men down in the hole. It's really pushing the state of the art. It depends on what drilling company you talk to as to how optimistic or pessimistic an answer you get."

The Nevada tuff. The investigation of Nevada tuff—a rock formed not from the extrusion of lava flows but from the welding together of pumice, ash, and other material hurled out of volcanoes in explosive eruptions—is going on at Yucca Mountain, in an area that takes in the southwest corner of the Nevada Test Site and extends over onto other federally owned land. This location seems to have considerable potential as an area for disposal of radioactive waste. For one thing, the test site, which covers 1350 square miles, is already contaminated from three decades of nuclear weapons testing and presumably will be kept under tight institutional control for a long time to come. For another, some 1600 to 2000 feet of the tuff lies above the water table and this "unsaturated zone" may constitute an excellent geologic medium for radwaste disposal.

But some major technical issues have arisen in the Yucca Mountain investigation and remain unresolved. For instance, a potential earthquake problem came to light as the result of tests conducted only last spring. The tuff was found to be under high tensional tectonic stresses that tend to separate the rocks—and this makes existing faults in the area susceptible to movement in the event of a sizable earthquake in the larger region, which is seismically active.

William J. Broad, who has been a News and Comment reporter since 1978, is leaving *Science*. He is joining the science staff of the *New York Times*. —S.

From a technical standpoint this finding has not been considered particularly alarming; many mines have survived earthquakes, and, it is felt, a properly engineered Yucca Mountain repository could withstand such an event. Nonetheless, according to William W. Dudley, the USGS coordinator for the welded tuff investigation, the discovery that the probability of earthquake activity at the site is greater than was once believed, though perhaps not greater than 1 in 10,000 for any one year, created a stir among the project managers because of the regulatory and political problems that might be provoked.

DOE has reason enough to take such problems seriously, because, by some indicators, the Nevada political environment for radwaste disposal has changed from warmly receptive to coldly hostile. As recently as 1978 a radwaste repository was viewed by Nevada political leaders as a possible economic boon. But during the last few years both Governor Robert List, a Republican, and the Democratic candidate who beat him in November, Attorney General Richard Bryan, have led a crusade to shut down a commercial low-level waste facility at Beatty, not far from the Nevada Test Site.

Why this change in the political climate? In an interview in early 1981, Governor List said, "It goes back to the atmospheric testing of the 1950's. The AEC misled the public. People don't trust the authorities. They are cynical. We have families who remember, survivors who litigate in the courts, high public awareness."

Salt beds and salt domes. A fundamental concern on the part of officials in the salt states—particularly Utah, Texas, and Mississippi—is that DOE has not stuck to what was to have been a sequential, step-by-step approach to site screening and selection. Instead, to keep from having to abandon its plan to select a salt site for an exploratory shaft this coming May, DOE has chosen to go to a dual-track approach. Construction of the exploratory shaft will proceed while at the same time the collection of hydrologic data continues—data on which originally the site's selection for full "characterization" was to have in part been based.

For either bedded or dome salt the cost of constructing an exploratory shaft and doing the necessary in situ tests is expected to run somewhere between $30 million and $50 million. Thus, by going to this phase without adequate hydrologic data, DOE is gambling that the site will not be disqualified on the basis of information that comes in from test wells located around the site—information which could be gathered *before* the costly shaft is built if more time were allowed.

William Fisher, director of the Texas Bureau of Economic Geology, observes that something else besides money is being put at risk—DOE and the waste program's credibility. "I personally would prefer that they not take that risk," he says. According to Fisher, DOE has so little hydrologic data for the Palo Duro Basin, where a specific site remains to be pinpointed, that geohydrology cannot be used as a screening tool. Yet in and around the areas of interest there is, he says, some evidence within the formation of "interior dissolution."

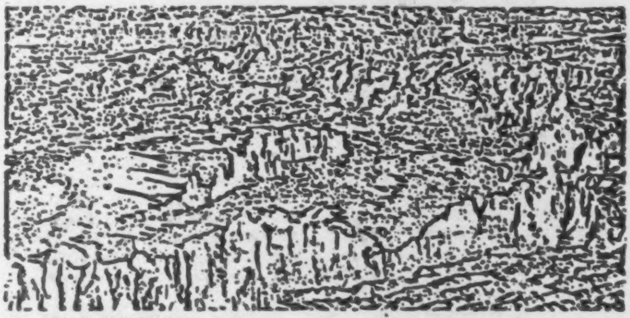
In March 1981 the USGS advised DOE by letter that the chances for predicting subsurface geologic and hydrologic conditions were "significantly better in bedded salt than in dome salt." The basic reason for this, as indicated in the USGS letter, is that, while bedded salt formations can vary, they are in general characterized by a relatively simple "layer cake" geology of salt interbedded with other kinds of material and overlain by rocks from the erosion of surrounding highland areas.

Salt domes, on the other hand, are far more complex. They were formed when deep layers of bedded salt, being relatively light and buoyant, pushed up through weak places in the overlying rock, rising thousands of feet until they approached the earth's surface, where characteristically the dissolving action of groundwater on the salt and the consolidation of less soluble materials has formed a caprock.

"A good way to visualize it," says Smedes, "is to take a bunch of colored cloths or old rags and let each color represent a different rock type and have them stacked up like a layer cake, and then draw this entire mass up through a hole you've made by thumb and finger

ger. You'll notice there are very complex vertically oriented folds, highly convoluted. Then if you snip part of that off and make a horizontal section, you'll see how complicated these crenulations are, largely vertically oriented but really like a marble cake. To the extent that these different rock types have desirable and undesirable hydrologic or mechanical properties, you can see the difficulty, the near impossibility, of trying to predict or determine ahead of time what the configuration is."

Complex as dome salt may be, all salt, as a generic rock type, presents complications because of the brine that it contains. The brine, as has been known since the 1960's, tends to migrate toward a heat source and, unless excessive temperatures are avoided, waste canisters could become immersed in a hot, highly corrosive bath.



Canyonlands National Park

A promising bedded salt site is less than a mile from the park. Collection of hydrologic data may require drilling in the park itself.

For the most part the brine exists as microscopic "inclusions" in the salt. But it can also occur in large pockets, sometimes under pressure sufficient to blow out a well or create havoc in a mine. Twice now over the 8 years that DOE's Waste Isolation Pilot Plant (WIPP) project for military transuranic waste has been in progress near Carlsbad, New Mexico, drilling rigs have hit brine pockets.

The last time was November a year ago when DOE, acting at the insistence of state officials, sought to determine the nature of an anomaly that had been detected in a seismic survey near the north end of the proposed repository. Although not a show stopper, the discovery of this brine pocket, together with indications of some other irregularities anomalies present at depth, led DOE

the facility is to be built, from the north end of the site to the south end. Major brine pockets, incidentally, seem to be associated more with bedded salt than dome salt.

While salt beds are in general simpler than salt domes, DOE's investigation of the bedded salt of the Paradox Basin in Utah has not followed a happy or predictable course. Test boreholes have been drilled at four locations in the basin, and, unluckily, the best of them from a geologic standpoint has seemed to be a site in Davis Canyon within less than a mile of Canyonlands National Park.

Moreover, according to Robert J. Dingman, a consultant to the Utah state geologist, the most likely path for any radionuclide transport by groundwater is toward the park and the Colorado River. Collection of the relevant hydrologic data will require borehole drilling inside the park itself, Dingman believes. This requirement, if confirmed (DOE disputes Dingman's finding), could ignite further controversy about the exploration for radwaste disposal sites on the edge of a national park.

Last July, Utah's Governor Scott Matheson, disturbed at a DOE decision that the selection of a salt site for an exploratory shaft shall not be subject to a full environmental impact review, ordered state agencies to withhold all assistance from DOE, for example, denying permits for the transport of overweight drilling rigs on state roads. The effect has been to put the Paradox Basin investigation under a virtual moratorium.

Numerous scientific groups, in the United States and abroad, have concluded that the concept of the deep mined for the disposal of

American experience to date in four rock types—basalt, tuff, and bedded and dome salt—shows that carrying out this concept is no simple, straightforward engineering task. A USGS official, testifying before a congressional committee last June, cautioned: "How successfully and quickly [the major geologic issues] can be resolved remains uncertain, in our opinion. Answers to many of the questions require innovative experimental procedures of large geometric dimension and long time periods."

Another authority, Paul A. Witherspoon, until recently head of earth sciences at the Lawrence Berkeley Laboratory and a leading expert on granite as a disposal medium, has proposed to DOE and the NRC, thus far unsuccessfully, that for every rock type and every candidate site a large-scale, 5- to 10-year experiment costing up to $39 million should be conducted to simulate the effect of heat from waste canisters on the rock mass.

According to Witherspoon, the experiment would serve mainly to influence repository design and the spacing of the waste packages but it might in some cases reveal a site to be unsafe and unacceptable. "I've heard a lot of program managers say, 'If we find a problem, we'll engineer around it.' That, in my opinion, is a very naive approach," Witherspoon told *Science*.

Despite all such cautionary advice from the experts, the cliché that "radioactive waste disposal is a political but not a technical problem" continues to be heard. It reflects a misapprehension of the realities of geologic disposal which is obviously quite widely held in Congress as well as in nuclear industry circles.

In 1970 the geologic disposal program suffered a political setback from which it has never fully recovered when the Atomic Energy Commission (AEC), acting precipitiously, announced that the nation's first repository would be built in a salt mine at Lyons, Kansas. The proposal soon had to be withdrawn, for the site was shown to be ill-chosen and possibly unsafe. DOE is not likely to make, or to be allowed to make, mistakes as obvious as those the AEC made at Lyons. But unless the technical realities of geologic disposal are respected for what they are, with NWTS schedules adjusted as needed to fit those realities, further political embarrassments could well lie ahead.—LUTHER J. CARTER

A contributing writer to Science, Carter is doing a study for Resources for the Future of the nuclear waste problem as a

Question 12: In a 1987 paper by Bernard Cohen ("Effects of ICRP Publication 30 and the 1980 BEIR Report on Hazard Assessments of High-Level Waste", *Health Physics*, v.42, No. 2, February 1982) the toxicity of high-level radioactive waste and spent nuclear fuel as a function of time is recalculated, and Cohen concludes that the most recent relevant data implies a *longer* period than has previously been assumed during which the fuel and waste are more toxic that natural uranium. In the case of high-level waste the previously assumed approximately 1000-year period of severe toxicity must now be extended to 10,000 or perhaps 100,000 years.

Please provide the Committee with your views on this paper and its implications for both geologic disposal of spent fuel and/or reprocessed high-level nuclear waste and long-term monitored, retrievable storage of such spent fuel or high-level waste.

Answer: The DOE must comply with general radiation limits for disposal of nuclear wastes prescribed by the Environmental Protection Agency. These radiation limits, currently in draft from [Federal Register 47(250): 58196-58206), are presented in terms of curie release limits to the accessible environment during the first 10,000 years after the permanent closure of a geologic repository. The DOE has recently testified before EPA that it would like the flexibility to meet either the curie release limit as proposed by EPA or a dose limit. The dose limit would enable DOE to account for specific site characteristics and reflect any refinements or changes in dose calculations.

In general, if the regulatory organizations revise the assumptions regarding the toxicity of long-lived radioisotopes, it would directly affect the estimates of long-term risk from any waste management system. For systems which rely on active human involvement to assure waste isolation, such as monitored retrievable storage, there are certainly implications as to how long such systems would need to be maintained and/or regularly replaced.

The dosimetric data and techniques in ICRP-30 are currently under review by a working group under the auspices of the National Council on Radiation Protection, a guiding organization in the health physics community in this country. Indications are that the NCRP will not adopt or endorse the ICRP-30 data and techniques in toto because certain fundamental aspects seem equivocal (see "Neptunium - the Neglected Actinide: A Review of the Biological and Environmental Literature ," Radiation Research. Vol. 90, pg 1-32, 1982 and "Neptunium - the Neglected Actinide: Corrections and Extensions," Ibid, Vol. 92, pg. 0-0, 1982).

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EFFECTS OF ICRP PUBLICATION 30 AND THE 1980 BEIR REPORT ON HAZARD ASSESSMENTS OF HIGH-LEVEL WASTE

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Abstract—ICRP Publication 30 (ICRP30) gives the radiation dose to various body organs in Sv per Bq, which are readily translated into rad per curie ingested for various radioisotopes; the 1980 BEIR Report (BEIR III) gives the risk of fatal cancer per rad of dose to each body organ; the ORIGEN 2 Code gives the curies per tonne of initial uranium fuel in high level waste and in spent fuel. The product of these, Ci/tonne × rad/Ci × risk/rad gives the risk/tonne in terms of fatal cancer doses, if ingested, per tonne of uranium. When the resulting curves are compared with those calculated previously (based on ICRP Publication 2 and the 1972 BEIR Report), the hazard is less for the first century but much more thereafter. The principal sources of this greatly increased hazard is the 100-fold increase in absorption through the gut for ^{237}Np in ICRP 30, plus the high cancer risk from radiation to liver in BEIR III. Some consequences of these changes and some scientific questions relevant to ascertaining their validity are discussed.

INTRODUCTION

EVALUATIONS OF potential dangers from buried high level radioactive waste nearly always conclude that scenarios in which it contaminates food or water supplies are of dominant importance. Safety analyses therefore depend heavily on the ingestion hazard in the waste. This is most frequently expressed in terms of the quantity of water in which it would have to be diluted before that water would satisfy the drinking water standards for the general public, known as radioactivity concentration guides (RCG), listed in 10 CFR 20. This is shown in Fig. 1 for the waste generated by one tonne of uranium fuel in producing 33,000 MW-days of energy in a pressurized water reactor (PWR); Fig. 1 includes plots of this hazard index as a function of time for various individual radioactive isotopes as well as the total for all combined.

The RCG are based on the maximum permissible concentrations (MPC) from ICRP Publication No. 2 (ICRP59). The MPC was determined essentially by the radiation dose commitment to various body organs resulting from ingestion of a radionuclide, i.e. the rad/Ci ingested. Since the 1972 BEIR Report (NAS72) gave estimates of the cancer risk/rad of exposure to various body organs, these could be multiplied by the rad/Ci from ICRP-2 and summed over body organs to obtain the total cancer risk/Ci ingested. When this is multiplied by the number of curies in the high level waste, one obtains the number of "cancer doses" (CD) from each radionuclide in the waste, and this may be summed over radionuclides to obtain the total hazard in CD. The results of such a calculation (Co77) are shown in Fig. 2. To clarify the meaning of CD, the value of 8×10^3 CD at $t = 10^4$ yr in Fig. 2 means that if the high level waste derived from one tonne of uranium fuel were converted into digestible form and fed to a large number of people 10,000 yr after reprocessing, we could expect 80 cancers to result. In view of the linear relationship between dose and cancer risk, this result is independent of the number of people involved or the way the material is distributed among them, so long as no one person ingests a fraction approaching 1/800 of the total.

In quantitative risk assessments, one estimates the fraction of the radioactivity in the waste that will reach human stomachs each year, multiplies it by the curve in Fig. 2, and integrates over time. In most models, the fractional release per year vs time is different for each radionuclide, so the individual curves in Fig. 2 must be multiplied by separate functions before adding and integrating.

A major shortcoming in these procedures is that the rad/Ci from each radionuclide to each body organ is taken from ICRP-2, which was published in 1959. Some minor updating was incorporated into Fig. 2, but a complete overhaul of the data used in ICRP-2 has now become available in ICRP Publication 30 (ICRP79). The major purpose of this paper is to substitute the latter for the former in the calculations and comment on the important differences this makes. Another purpose is to incorporate the 1980 BEIR Report (NAS80) into the calculations as a substitute for the 1972 BEIR Report. (We refer to these as BEIR-III and BEIR-I, respectively.) One difference between the two is that the bone cancer risk/rad is much smaller in BEIR-III, and this might be important since the calculations leading to Fig. 2 were completely dominated by the bone cancer risk. A final purpose is to explore differences that may be introduced by use of the new and improved ORIGEN Code (Cr80) for calculating the composition of the high level waste as a function of time.

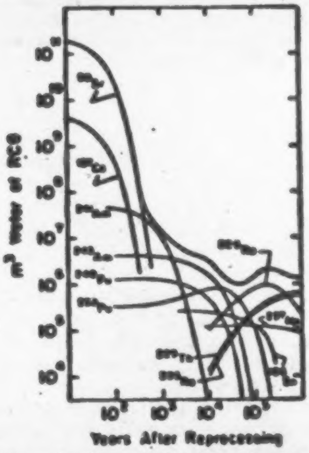

FIG. 1. Ingestion hazard of high level waste based on RCG. This is the quantity of water needed to dilute the radioactivity in the waste derived from 1 tonne of initial uranium fuel to drinking water standards based on the RCG of 10 CFR 20, vs time after reprocessing for fuel reprocessed 160 days after removal from reactor. Heavy line is the sum of the individual curves.

THE NEW DATA

ORIGEN 2 vs ORIGEN 1

Over the past 5 yr, a great deal of effort has

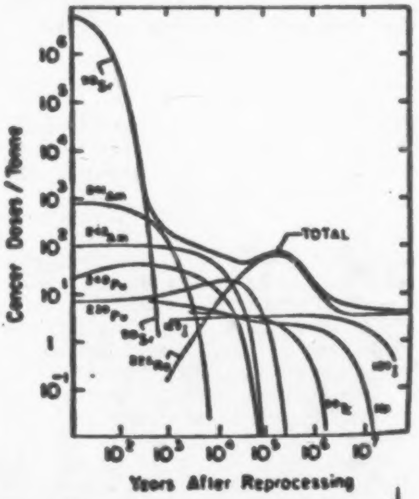

FIG. 2. Cancer doses per tonne of initial uranium fuel vs time after reprocessing. These are calculated from BEIR I and ICRP 2, with some updating. From (Co77).

been devoted to improving the ORIGEN Code used for calculating the quantity of each isotope in the waste as a function of time (Cr80). This has involved improving the computer code itself (naming the new version ORIGEN 2) and improving the input data on cross sections, fission product yields, decay schemes and energies, reactor models, etc. The results are compared in Table 1 in terms of Curies per metric tonne of intial uranium (Ci/te) at specific times, as calculated with ORIGEN 1 in 1975 and with ORIGEN 2 in 1980. While many differences are evident, it is clear that they are too minor to be highly significant in treating the hazards of radioactive waste.

BEIR III vs BEIR I

Table 2 shows comparisons between the risk per rad from BEIR I and BEIR III. In cases where interpretations are required for use of the latter, these are taken from (Co81). BEIR III uses a linear-quadratic dose dependence for low-LET radiation, but we consider only the low dose region (< 100 rad) where the linear term predominates.

Table 1. Data on various radioactive isotopes in high level radioactive waste. The Ci/te is the number of curies per tonne of initial uranium in the fuel for each radioisotope at the time indicated according to ORIGEN 1 Code calculations using input data as of 1975 and ORIGEN 2 calculations with 1980 data. The rad/Ci is the dose to various body organs per curie ingested according to ICRP 2 (ICRP59) and ICRP30 (ICRP79). Where other body organs are important, those organs are specified before the listing of the rad/Ci in the "other" column. The risk/Ci is the product of the rad/Ci from ICRP 30 and the risk/rad from Table 2

Iso-tope	time (yr)	Ci/te		rad/Ci (x 10^5)									risk/Ci					
		1975	1980	marrow	bone(surf) IC-59	bone(surf) IC-80	liver IC-59	liver IC-80	LLI IC-59	LLI IC-80	Other IC-59	Other IC-80	marrow	bone**	liver	LLI	other	total
^{90}Sr	10	60K	57K	.7	7.6	1.6	-	-	.038	.067	-	-	15	.7	-	.4	-	16
^{137}Cs	10	66K	59K	-	-	-		whole	body	-	.032	.040	-	-	-	-	8.8	8.8
^{244}Cm	30	-	1.0K	.08	.011	1.0	.001	.34	.006	.01	-	-	1.7	27	72	2	-	103
^{93}Zr	1K	1.9	1.8	.0027	6x10^-6	.034	-	-	.0024	.0037	-	-	.067	.017	-	.003	-	.1
^{99}Tc	1K	14	13	-	-	-	-	stom	ach	-	-	.013	-	-	-	-	.16	.16
^{135}Cs	1K	.39	.36	-	-	-	-	whole	body	-	.0061	.0078	-	-	-	-	.05	.05
^{129}I*	1K	.052	.032	-	-	-	-	thy	roid	-	9.4	9.3	-	-	-	-	85	85
^{237}Np	1K	.27	.35	2.8	.005	.38	.010	7.6	.006	.01	-	-	60	570	2300	2	-	2900
^{239}Pu	1K	2.1	2.0	.03	.015	.40	.010	.08	.006	.01	-	-	.6	11	24	2	-	38
^{240}Pu	1K	8.0	5.1	.03	.015	.40	.010	.08	.005	.01	-	-	.6	11	24	2	-	38
^{241}Am	1K	35	32	.16	.015	2	.027	.40	.006	.01	-	-	3.4	54	120	2	-	180
^{243}Am	1K	17	16	.16	.018	2	.027	.40	.006	.01	-	-	3.4	54	120	2	-	180
^{238}U	1M	.0016	.0016	.013	.00015	.19	-	-	.005	.009	-	-	.27	5.1	-	2	-	8
^{234}U	1M	.0042	.0043	.013	.00018	.2	-	-	.006	.009	-	-	.27	5.6	-	2	-	8
^{230}Th	1M	.0055	.0055	.064	.038	.67	.01	-	.006	.01	-	-	1.1	18	-	2	-	21
^{226}Ra	1M	.0055	.0056	.11	38	1.3	-	-	.004	~.06	-	-	2.3	35	-	2	-	40
^{210}Pb	1M	.0056	.0056	.33	.30	4.1	.37	1.1	-	-	-	-	6	111	330	-	-	447
^{236}U	1M	.0026	.0022	.013	.00015	.19	-	-	.006	.01	-	-	.27	5.1	-	2	-	8
^{232}Th	1M	10^{-7}	.040	.28	.038	2.5	.030	-	.005	.008	-	-	5.9	95	~	2	-	103
^{233}U	1M	.29	.27	.014	.0002	.22	-	-	.006	.009	-	-	.29	6	-	2	-	8
^{229}Th	1M	.29	.27	.35	-	4.4	-	-	.005	.01	-	-	7.3	119	-	2	-	129
^{225}Ra	1M	.29	.27	.031	-	.28	-	-	.005	.01	-	-	.05	9	-	2	-	12
^{235}U	1M	.00034	.00032	.013	.00015	.19	-	-	.006	.01	-	-	.27	5.1	-	2	-	8
^{227}Ac	1M	.00034	.00032	1.8	.037	12	.004	2.8	.0006	-	-	-	21	304	840	-	-	1165
^{231}Pa	1M	.00034	.00032	1.8	.08	13	.019	-	.006	-	-	-	21	351	-	-	-	372

*The ^{129}I data includes that removed in reprocessing and perhaps stored separately.

**Uses risk = 27×10^{-6}/rad to bone surfaces, the larger of the two choices in Table 2.

Table 2. Fatal cancer risk/rad (× 10^{-6}) to various body organs according to the 1972 and 1980 BEIR Reports. From (Co81)

site	BEIR-I		BEIR-III	
	low-LET	alphas	low-LET	alphas
whole body	180	–	120	–
bone marrow – leukemia	20	200	22	22
bone	[illegible]	300(60)*	–	–
bone surface	–	–	0.47	27.0**
liver	<10	<2000	6.8	300
intestine	<10	<2000	3.3	300
thyroid	–	–	7	–
stomach	<10	–	12	–

*The figure in parenthesis is for radium.

**BEIR-III gives a linear and a quadratic estimate, and states no preference between the two. For the quadratic estimate, the risk is essentially zero at low doses.

For low-LET whole body radiation, BEIR III adopts a risk 2/3 as large as that in BEIR I, 120×10^{-6}/rad vs 180×10^{-6}/rad. For leukemia there is little difference between the two for low LET radiation. In principle there is a large difference for alpha particle exposure, but ICRP 2 did not give an explicit treatment for dose to bone marrow, and there is excellent experimental evidence that α-emitters cause bone cancer much more frequently than leukemia, so leukemia induction by alpha emitters has generally been ignored in past studies.

There is a major difference in treatments of bone cancer risk between BEIR I and BEIR III. The former is based on dose to the total bone, whereas the latter considers only dose to bone surfaces. The latter gives a risk/rad whereas the former gives a risk/rem where the rem/rad conversion includes a radiation distribution factor as well as a factor depending on LET (linear energy transfer). It is therefore not very useful to make comparisons at this stage of the discussion.

BEIR I does not give specific risks for intestinal or liver cancer, but the former is included in cancers of the gastrointestinal tract and the latter is presumably included among "all other cancers", so the risks for these categories are listed in Table 2 as upper limits. Liver cancer is discussed extensively in BEIR III but intestinal cancer is not, so a default estimate is used (Co81).

ICRP 30 vs ICRP 2

Dose conversion factors, defined as the dose to specific body organs per curie of a radionuclide ingested, depend on various metabolic data—the transfer probability from the G-I tract into the blood stream (f_1), the transfer probability from the blood stream into the body organ (f_2—called f_2' in ICRP 2) and the *rate of elimination* from the body organ (inversely related to biological half life). A great deal has been learned about these factors between 1959 and 1980, so it is not surprising that there should be important differences between ICRP 2 and ICRP 30. The most important of these are shown in Table 1 in the columns labelled rad/Ci.

ICRP 30 gives dose commitment conversion factors in units of Sv/Bq which converts to rem/Ci by multiplying by 3.7×10^{12}. consistently uses 1 rad = 20 rem for α-part cles, so for these 1 Sv/Bq = 1.85×10^{11} rad/Ci. ICRP 2 does not directly give rad/Ci, but rather it lists MPC defined roughly* as the concentration of the radionuclide in water (Ci/m^3) such that the annual average human ingestion (0.8 m^3) would give a dose commitment of 30 rem to bone or thyroid, 15 rem to soft tissue organs, or 5 rem to the whole body. For α-particles it uses 10 rem/rad except that for dose to bone from elements other than radium it uses 50 rem/rad.

For β-emitters it uses 1 rem/rad for all organs except bone for which it uses 5 rem/rad. Thus for alpha emitters other than radium, the dose conversion factor for bone is obtained from noting that 1 MPC (Ci/m^3) × 0.8 m^3 = 30 rem × 1 rad/50 rem, or

rad/Ci = (30/50)/0.8 MPC = 0.75/MPC
α, bone (other than radium).

Other important examples are:

rad/Ci = (30/10/0.8 MPC = 3.75/MPC
α bone (radium)
rad/Ci = (30/5)/0.8 MPC = 7.5/MPC β, bone
rad/Ci = 30/0.8 MPC = 37.5/MPC
γ, bone; β, γ thyroid
rad/Ci = 15/0.8 MPC = 18.8/MPC
$\beta\gamma$, liver, intestine
rad/Ci = (15/10)/0.8 MPC = 1.88/MPC
α, liver, intestine
rad/Ci = 5/0.8 MPC = 6.25
$\beta\gamma$, whole body.

These were used to convert the MPC in ICRP 2 to the rad/Ci listed under "ICRP 2" in Table 1. We now discuss the comparison between these and the ICRP 30 values.

One interesting difference between ICRP 2 and ICRP 30 involves the bone cancer risk. As is evident from Figs. 1 and 2, the hazards estimated from the old calculations were dominated by the bone cancer risk from ^{90}Sr and ^{226}Ra, but these are very much reduced here. For ^{90}Sr, the rad/Ci is reduced by a factor of (7.5/1.6 =)4.7, and the risk/rad from Table 2 is reduced by a factor of (6/0.47 =)13, so the overall risk of bone cancer from ingestion of ^{90}Sr is reduced by a factor of 60. For ^{226}Ra, the rad/Ci is reduced by a factor of 30, and there is a factor of 2 reduction in the risk/rad from Table 2, reducing the overall risk of ^{226}Ra ingestion by a factor of 60.

One source of the reduction in rad/Ci is in the much more elaborate modelling of alkaline earth metabolism based on very extensive data; this is reviewed in ICRP Publication 20 (ICRP72). According to ICRP2, 30% of the ^{90}Sr in the blood stream deposits in bone and is eliminated with a 17 yr half life, so 21% is left after 9 yr and 10% is left after 27 yr; but according to ICRP 30, these are only 6.8% after 9 yr and 2.8% after 27 yr.

A more important source of discrepancy is that ICRP30 (and BEIR III) consider only the dose to bone surfaces as relevant to cancer induction so the great majority of radiation from ^{90}Sr and ^{226}Ra, which distribute through the volume of the bone, is ineffective. As a result, the importance of these radioisotopes in the radioactive waste is greatly reduced, although the leukemia risk from ^{90}Sr is still important.

On the other hand, the bone cancer hazard from Np, Pu, and Am is greatly enhanced in ICRP 30. The comparison with ICRP 2 is somewhat clouded by the fact that it deals with dose to the whole bone rather than to bone surfaces, but as a rough approximation, this may be compensated by noting that the risk/rad for these in Table 2 is 10 × higher than the risk/rad to bone surfaces (300 vs 27), whence the rad/Ci from ICRP 2 should be multiplied by 10 before comparison with ICRP 30.

When this is done for the Pu isotopes, we see that the ICRP 30 rad/Ci are 2.7 times those in ICRP 2. There are two clear differences in the metabolic models: f_1 (the transfer from G-I tract to blood stream) is 3.3 times higher in ICRP 30 (10^{-4} vs 3×10^{-5}), and f_2 (the fraction in the blood stream which deposits in bone) is 1.8 times lower (0.45 vs 0.8), so these two factors account for 2/3 of the difference. The remainder of the difference is due to the crudeness of comparing dose to bone volume with dose to bone surfaces.

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*The dose commitment concept was not used in ICRP 2, but the procedure used was exactly equivalent in most cases and within less than a factor of 2 of being equivalent in all cases.

For the Am isotopes, the ICRP 30 value for rad/Ci in Table 1 is 12 times higher than the equivalent value from ICRP 2. In the former, f_1 is 5 times higher (5×10^{-4} vs 10^{-4}) and f_2 is 1.8 times higher (0.45 vs 0.25), so these two factors account for 3/4 of the difference. For ^{237}Np, the discrepancy is very much larger, a factor of 144. In this case, the ICRP value of f_1 is 100 times larger (10^{-2} vs 10^{-4}) and f_2 is the same (0.45 in each case), so once again about 70% of the discrepancy is explained by changes in the metabolic model.

There is also an increase in the rad/Ci to bone from Th and U. For Th, the ICRP 30 value of f_1 is twice as large (2×10^{-4} vs 10^{-4}), and f_2 is the same (0.7). For U, the rad/Ci is dramatically increased because f_1 is 500 times higher in ICRP 30 (0.05 vs 10^{-4}); f_2 is 14 times smaller (0.023 vs 0.33), and the biological half life is 17 times longer (5000 vs 300 days). In summary, the bone cancer risk is increased for all actinides, but by widely varying factors; by well óver two orders of magnitude for U and Np, by a little over 1 order of magnitude for Am, and by factors of 2–3 for Th and Pu.

Even more important are the increases in rad/Ci for liver between ICRP 2 and ICRP 30. For Pu, this is by a factor of 8, due to the factor of 3.3 increase in f_1 and a factor of 3 increase in f_2, somewhat compensated by a shorter biological half life (40 vs 100 yr). For Am, the liver dose from ICRP 30 is 15 times larger, due to the 5 times larger f_1, a slightly larger f_2 (0.45 vs 0.35), and a much longer biological half life (40 vs 10 yr). For Np, the rad/Ci for liver is increased by a factor of 760, due to the 100 fold increase in f_1 and a nine fold increase in f_2 (0.45 vs 0.05), with only slight compensation from a shorter biological half life (40 vs 150 yr). These increases, especially for Am and Np, have an enormous effect on the results.

The other important change between ICRP 2 and ICRP 30 is treatment of bone marrow as a separate organ. Since the leukemia risk from Table 2 is 50 times higher than the bone cancer risk for low-LET radiation, this has an important effect on the results.

The difference between whole body radiation from Cs between ICRP 2 and ICRP 30 is largely due to the dominant biological half life being longer in the latter (170 vs 70 days). For I, the only difference is a slightly shorter biological half life in ICRP 30 (120 vs 138 days), but even this is somehow compensated in the details of the calculation so the rad/Ci to the thyroid is essentially unchanged.

RESULTS OF CALCULATIONS

When the rad/Ci (based on ICRP 30) from Table 1 are multiplied by the risk/rad from Table 2, the results are risk per curie for the various types of fatal cancer. These are listed as "risk/Ci" in Table 1, and their sum gives the total risk of fatal cancer per curie ingested, listed in the last column of Table 1. The ratio of these risks/Ci to those in Co77 are: ^{90}Sr–1/7, ^{226}Ra–1/57, ^{237}Np–440, ^{239}Pu–8.5, and ^{241}Am–40.

We see that the risk from ^{90}Sr ingestion is dominated by leukemia, with 20 leukemia cases for each case of bone cancer. This seems surprising since animals injected with ^{90}Sr almost always get bone cancer rather than leukemia (Fi68), but this is clearly an inevitable conclusion from the BEIR III risk estimates. In this connection it is interesting to note that the reduced hazard from ^{90}Sr brings ^{137}Cs into the picture as a non-negligible contributor.

The results for Np, Pu and Am show that liver cancer is much more important than bone cancer for these elements. There are two alternate bone cancer risks for α-emitters listed in Table 2 and the larger of these was used to derive risk/Ci in Table 1, but this makes little difference because of the predominance of liver cancer. For uranium, thorium, and radium, however, bone cancer is still dominant.

The risk/Ci in the last column of Table 1 are listed in Table 3 where they are used to calculate the number of cancer doses (CD) per tonne of initial uranium fuel. Some radioisotopes, not listed in Table 1 because they are not included in ICRP 30 (Parts I and II), are listed in Table 3 with rough estimates of their risk/Ci in parentheses. In all cases, these are small enough for those radioisotopes to be neglected in hazard analyses. Table 3 gives calculations of CD for both

Table 3. Calculations for Fig. 3, 4 and 6. Ci/tonne are as in Table 1 except that data for spent fuel are also listed. Risk/Ci are from the last column of Table 1. CD/tonne is the number of fatal cancer doses per tonne of initial uranium fuel; it is the product of risk/Ci and Ci/tonne. ALI are from ICRP 30 and are used to obtain Fig. 6. Risk/ALI is the product of risk/Ci and Ci/ALI. En means $\times 10^n$

radio-nuclide	HL (yr)	t (yr)	Ci/tonne HLW	Ci/tonne spent fuel	Risk/Ci	CD/tonne HLW	CD/tonne spent fuel	Ci/ALI ($\times 10^{-6}$)	Risk/ALI ($\times 10^{-6}$)
^{90}Sr	28.8	10	5.7E4	5.7E4	16	1.0E6	1.0E6	2.7	43
^{137}Cs	30.2	10	8.2E4	8.2E4	5.0	4.0E5	4.0E5	10.0	50
^{151}Sm	90	10	3.3E2	3.3E2	(.1)	-	-	-	-
^{154}Eu	8.5	10	4.5E3	4.0E3	(.3)	-	-	-	-
^{244}Cm	18	10	1.0E3	1.0E3	160	1.6E5	1.6E4	.06	85
^{238}Pu	87	10	1.0E2	2.2E3	30	3000	7.0E4	1.3	40
^{79}Se	6.5E4	1K	4.0E-1	4.0E-1	(?)	-	-	-	-
^{93}Zr	1.5E6	1K	1.8E0	1.8E0	.1	.18	.18	270	27
^{99}Tc	2.1E5	1K	1.3E1	1.3E1	.15	2.0	2.0	270	40
^{107}Pd	6.5E6	1K	1.1E-1	1.1E-1	(?)	-	-	-	-
^{126}Sn	1E5	1K	7.7E-1	7.7E-1	(?)	-	-	-	-
^{129}I	1.6E7	1K	3.3E-4	3.3E-2	65	.002	2.0	1.9	124
^{135}Cs	3E6	1K	3.4E-1	3.4E-1	.05	.20	.20	80	40
^{237}Np	2.1E6	1K	3.0E-1	1.0E0	3300	1100	3300	.014	46
^{239}Pu	2.4E4	1K	2.6E0	3.1E2	30	75	1.1E4	1.1	42
^{240}Pu	6.6E3	1K	6.1E0	4.8E2	30	230	1.0E4	1.1	42
^{241}Am	433	1K	4.2E1	9.0E2	160	7000	1.6E5	.26	43
^{243}Am	7.4E3	1K	1.8E1	1.8E1	160	2900	2900	.26	43
^{235}U	7.0E8	1M	3.3E-4	2.0E-2	8	.0025	.22	1.9	16
^{227}Ac	-	1M	3.3E-4	2.0E-2	1106	.37	23	-	-
^{231}Pa	-	1M	3.7E-4	2.0E-2	372	.12	10	-	-
^{234}U	2.5E5	1M	4.3E-3	4.8E-1	8	.036	3.4	1.9	16
^{230}Th	8.0E4	1M	5.0E-3	4.0E-1	21	.12	8.7	1.1	23
^{226}Ra	1.6E3	1M	5.0E-3	4.0E-1	40	.21	16.4	.06	22
^{210}Pb	22	1M	5.0E-3	4.0E-1	447	2.4	200	.11	40
^{233}U	1.6E5	1M	2.7E-1	9.1E-1	8	2.1	7.3	1.9	16
^{229}Th	7.3E3	1M	2.7E-1	9.1E-1	120	35	117	.14	18
^{225}Ra	(14.8D)	1M	2.7E-1	9.1E-1	12	3.2	10.9	1.6	19
^{236}U	2.3E7	1M	3.3E-3	3.0E-1	8	.025	2.1	1.9	16
^{232}Th	1.4E10	1M	-	2.0E-4	180	-	.037	.19	30
^{238}U	4.5E9	1M	1.6E-3	3.3E-1	8	.013	2.6	2.2	18

reprocessed high level waste (with reprocessing 160 days after removal from the reactor) and for unreprocessed spent fuel. Reprocessing is assumed to remove 99.5% of the uranium and plutonium, but since ^{241}Pu (13 yr half life) is the source of ^{241}Am, early reprocessing also greatly depletes the ^{241}Am and its daughter ^{237}Np eventually appearing in the waste. The depletion of these plus the removal of uranium and other plutonium isotopes also reduces considerably the thorium and radium isotopes eventually appearing.

The CD/tonne columns of Table 3 plus the time variations obtained from the ORIGEN program are used to obtain the time dependence of CD shown in Figs. 3 and 4 for high level waste and spent fuel respectively. The CD are shown for each isotope, and the sums over all isotopes are also shown. These figures are the principal results of this paper.

From Fig. 3, we see that in the high level waste ^{90}Sr and ^{137}Cs are dominant only up to 200 yr, ^{241}Am is then dominant up to 1500 yr followed by ^{243}Am up to 10,000 yr, after

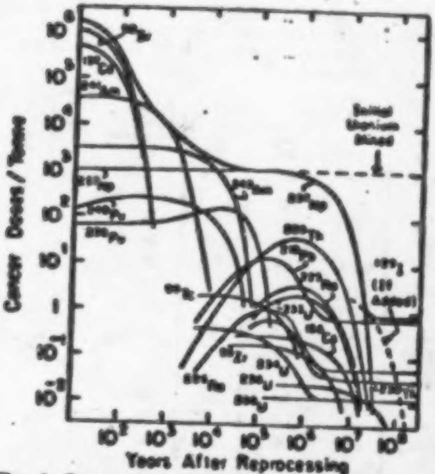

FIG. 3. Cancer doses per tonne of initial uranium fuel in reprocessed high level waste vs time after reprocessing, calculated from BEIR III and ICRP 30. Time dependences are from ORIGEN 2 Code, and normalizations are from Table 3.

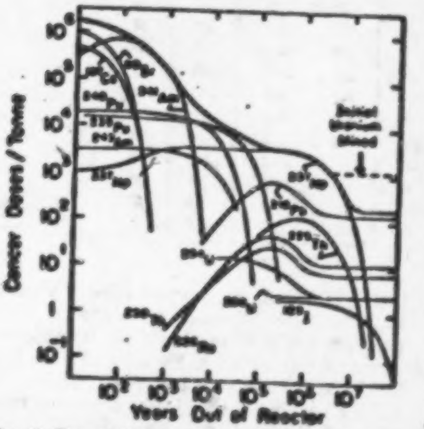

FIG. 4. Cancer doses per tonne of initial uranium fuel in unreprocessed spent fuel vs time after removal from reactor, calculated from BEIR III and ICRP 30. Time dependences are from ORIGEN 2 Code, and normalizations are from Table 3.

which ^{237}Np dominates up to 20 million years before the ^{238}U decay chain takes control. For the case of unreprocessed spent fuel, ^{90}Sr and ^{137}Cs are most important only for the first 30 yr while the ^{241}Am grows in from decay of ^{241}Pu; ^{241}Am then dominates until 2000 years when the plutonium isotopes take over until replaced by ^{237}Np after 50,000 yr; the latter then dominates until 15 million yr when the ^{238}U decay chain takes over.

It is interesting to compare the toxicity of the waste with that of the uranium ore originally mined to produce it. ^{238}U contains 0.3 Ci/tonne, and about 5 tonne, 1.65 Ci, must be fed into the enrichment plant to obtain tonne of uranium fuel. In natural uranium thi is accompanied by 0.075 Ci of ^{235}U. Th CD/tonne of the members of the ^{238}U deca chain in Column 6 of Table 3 total 520, whil for the ^{235}U decay chain (esp. ^{231}Pa and ^{227}Ac the total is 1540. The CD fed into th enrichment plant/tonne of uranium in fuel i then [(1.65 × 520) + (0.075 × 1540) =] 100 With some consideration for losses in millin and conversion to enrichment plant feed, thi becomes essentially equal to the hazard in th high level waste after 50,000 yr, and is withi a factor of 10 of the latter after 1000 yr.

The total toxicity curves from Figs. 2-4 a shown together in Fig. 5 for compariso purposes. We see that the previous estima of toxicity was about 4 times too high for th first 100 yr, but it dropped off much mor rapidly, becoming 30 times too low aft 1000 yr. It is between 10 and 30 times too lo from 300 yr to 600,000 yr, then drops to times too low at 1.5 million yr, and then ap proaches present estimates equaling them 15 million years and exceeding them by factor of 4 after 30 million yr.

It is apparent from Fig. 5 that the toxici of spent fuel greatly exceeds that of repr cessed high level waste by a considerab factor at all times after 100 yr. The excess is factor of 10 between 200 and 5000 yr, remains more than a factor of 3 at all tim thereafter, and it increases to a factor of 2 when the ^{238}U decay chain becomes domina after 20 million yr. On the other hand, t increased toxicity of reprocessed waste ov spent fuel was even larger in the previo estimates, and this was not considered to be an important reason for reprocessing.

For some purposes, it is interesting to estimate the toxicity of high level waste glass, converted into digestible form. Current thinking is that a waste glass canister would be about 0.2 m^3 in volume, weigh about 550 kg, and produce about 1 kw of heat 10 yr after reprocessing which means that it would contain the waste from about 1 tonne of uranium fuel. According to Fig. 3, this contains 1.5×10^6CD, whence a "lethal dose" is about $(550 \times 10^3/1.5 \times 10^6 =)$ 0.3 g, or 0.01 oz. It becomes 0.1 oz. after 100 yr, 1 oz. after 600 yr and 10 oz. after 15,000 yr.

Since ICRP 30 lists annual limits of intake (ALI) for each radioisotope, it is very easy to express the hazard in the waste in terms of ALI. One might expect this to be put into the ORIGEN code as a substitute for "m^3 of water at RCG". The ALI are listed in Table 3. The hazard in the waste is (Ci/tonne)/(Ci/ALI) = ALI per tonne of initial uranium in the fuel. This is plotted vs time in Fig. 6 for reprocessed waste. We see that Fig. 6 is quite similar to Fig. 3, and was obtained much more simply. To understand the difference between Fig. 3 and 6, the product of CD/Ci and Ci/ALI = CD/ALI is listed in the last column of Table 3. We see that the ratio of CD to ALI varies by only a factor of four for all radioisotopes considered, which indicates that relative differences between Figs. 3 and 6 are no more than that.

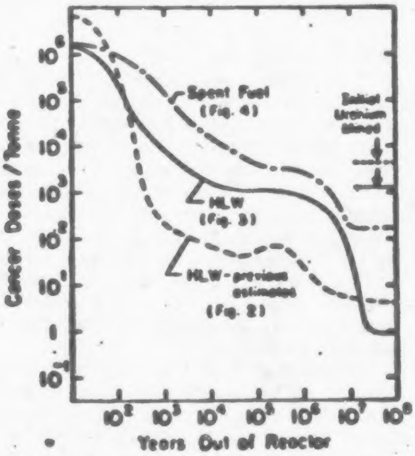

FIG. 5. Comparison of curves from Figs. 2–4.

CONSEQUENCES OF NEW RESULTS

Repository design

It is often said that a high level waste repository should be designed to maintain security for only about 1000 yr. The rationale for this position was based on the curve in Fig. 2, but this rationale clearly is much more questionable with the new results, and most especially if spent fuel is buried. In the latter case, the toxicity is still 10% of its initial value after 1000 yr, and does not reach 1% until after 7000 yr, and 0.1% until after 2 million yr.

The most important influence this might have on present design considerations is in the thickness of the casing, in present plans to be made of a titanium alloy. Sheets of minimal thickness have been proposed since

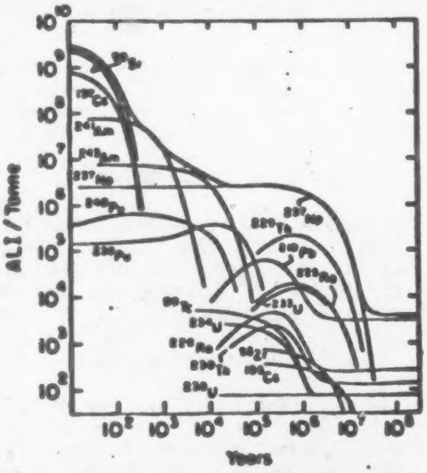

FIG. 6. ALI per tonne of initial uranium fuel in high level waste. Ordinate is curie per tonne of fuel/curie per ALI where ALI are from ICRP 30, listed in Table 3.

they would provide security for 1000 yr, but for longer term security one or more centimeters of thickness would seem to be in order.

Safety analyses

Because of the large differences between Figs. 2 and 3, safety analyses of waste repositories must all be redone. However, these turn out to be exceedingly simple. In view of their relatively short half lives, ion exchange hold-up virtually guarantees that ^{90}Sr, ^{137}Cs, ^{241}Am, and ^{243}Am will not escape (Co80), so everything is dominated by ^{237}Np because of its high toxicity in Fig. 3 and its relatively weak ion exchange retardation. Safety analyses then need be done only for that single radioisotope.

An analysis by the present author (Co80) concluded that 10^{-12} of of the material buried might be expected to reach human ingestion each year until 13 million yr, as might 10^{-4} of all remaining at that time. The number of cancer fatalities expected, F, is the number of CD reaching human ingestion, or

$$F = \int_0^{13M} 10^{-12}(CD)_0\, e^{-\lambda t}\, dt + 10^{-4}(CD)_0\, e^{-\lambda \cdot 13M}$$

where λ is the decay constant $= 3.2 \times 10^{-7}$ and $(CD)_0$ is the initial number of cancer doses in ^{237}Np. Evaluating the integral and recognizing that $e^{-\lambda \cdot 13M} \ll 1$, this becomes

$$F = (CD)_0[10^{-12}/\lambda + 10^{-4}\, e^{-\lambda \cdot 13M}].$$

From Table 3, there are 1120 CD/tonne, and 1 GWe-yr of electricity production discharges 33 tonne, whence $(CD)_0 = 1120 \times 33 = 3.7 \times 10^4$/GWe-yr. Inserting this and the values for λ gives finally

$$F = 0.17 \text{ fatal cancers/GWe-yr.}$$

This is 200 times larger than the result calculated from the earlier cancer risk estimates, and larger than effects of all other radioactivity releases from the nuclear industry combined.

An interesting and possibly important point in the above calculation is the role of "13 million yr". This is the time, T, at which the surface of the earth can be expected to erode down to the repository horizon for present average rates of erosion, $T = 13 \times 10^6$ yr, and the calculation assumes that all of the waste will be released into rivers at that time. However T is subject to considerable uncertainty depending on unpredictable geological conditions in the far future. It could be billions of years—some rock is that old—in which case the second term should be dropped and F is reduced to 0.11/GWe-yr. But on the other hand, T could be much shorter in which case the second term rapidly escalates. If it is a time short compared with the 2.1 million yr half life of ^{237}Np, F is increased by a factor of 20 to 3.4 fatalities/GWe-yr.

While T is unpredictable, other things being equal it is proportional to the depth of burial. This is, perhaps, a reason to consider deeper burial.

The dominant importance of ^{237}Np in the safety analysis suggests that renewed consideration be given to "waste partitioning", i.e. separation of the Np, Am, and other transuranics for separate disposal with no complications from heating caused by radioactive decay. According to Fig. 3, this would reduce the hazard in the residual waste by several orders of magnitude at all times after 500 yr.

Scientific implications

The dominant importance of ^{237}Np on the hazard from waste suggests that the data on which it is based should be subjected to intense scientific scrutiny, especially since they have changed so drastically. The relevant items here are f_1—the efficiency for transmission from the gastrointestinal tract into the blood stream (1.0%), f_2—the fractional uptake by liver (45%), the biological half life in liver (40 yr), and the cancer risk/rad for α-emitters in liver (300×10^{-6}) where the values in parantheses are those used in the present calculations.

The value of f_1 is from data on rats and appears to be inordinately high. It would seem worthwhile to check this with experiments on humans. For example ^{234}Np has a 4.4 day half life, no α-emission, and a strong

γ-ray and X-ray, so it should be detectable with a whole body counter if as much as 10 nCi is absorbed through the gut. With $f_1 = 0.01$, this requires ingestion of only 1 μCi, which would give a dose of perhaps 10 mrem. The author would be happy to volunteer for participation in such a measurement.

The data on f_2 and the biological half life are based largely on analogy with plutonium in animal experiments. Neptunium is chemically very different from plutonium, so animal experiments with neptunium should be undertaken to clarify these parameters. There is evidence that the analogy with plutonium, which is also used for americium, gives excessively large values of f_2 and biological half-life for that element (Ro80).

The liver cancer risk from alpha emitters is obtained from data on thorotrast patients, and is therefore somewhat suspect as possibly due to chemical toxicity. This question is equally relevant to plutonium and americium toxicity, and is being studied with animal experiments.

Acknowledgements—The author is greatly indebted to A. G. Croff (ORNL) for providing the output of the ORIGEN 2 Code, to F. D. Sowby (ICRP) and M. R. Ford (ORNL) for providing data from ICRP 30, part 2 very promptly after their release, and to C. M. Koplic (Analytical Sciences Corp) for useful discussion.

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DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1984

TUESDAY, MAY 3, 1983

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:22 a.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici, Warner, Ford, Matsunaga, and Melcher.

Also present: Paul Gilman and Elliot Chakoff, professional staff members; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. SPARK M. MATSUNAGA, A U.S. SENATOR FROM THE STATE OF HAWAII

Senator MATSUNAGA [presiding]. The subcommittee will come to order.

Unfortunately, the chairman has been called to the White House, but fortunately a Democrat is very seldom called to the White House, so I have been asked to open the hearings, and unfortunately, I can be here only for a half hour, and fortunately for me, there is at least one witness from Hawaii, and because I have to leave here in a half hour I am going to do this fairly. I am going to take the one who traveled the farthest to come here, and so I will begin this morning by introducing from the State of Hawaii one of the, if not the foremost authority on renewable energy, and as a matter of fact, no citizen of the State has done more to establish Hawaii as the Nation's natural energy laboratory than the witness I am about to introduce.

He is a distinguished research scientist, an engineer, a nationally recognized expert on alternative energy technologies. He was responsible for the establishment in 1974 of the Hawaii Natural Energy Institute, a research institute of great prestige dedicated to the study of renewable energy. He served as its first director, and he is its current director.

He took leave from the Institute and the University of Hawaii in 1977 and in 1978 to come to Washington and serve as scientific adviser to Mr. Robert Thorne, then Assistant Secretary for Energy Technology at the Department of Energy.

Upon his return to Hawaii he was appointed chairman of the Governor's Advisory Committee on Alternative Energy Development. In 1979 he was selected by the Hawaii Society of Professional Engineers as the society's engineer of the year for his work in the development of Hawaii's renewable energy resources.

He has been principal investigator on a number of renewable energy projects and has served as a consultant to the National Science Foundation. He has more than 40 technical reports and publications to his credit. One of these entitled, "Energy Self-Sufficiency for Hawaii" was published in Science magazine in June 1982.

He is the former dean of the Engineering School of the University of Hawaii and was recently interim dean of the Graduate Division of the University of Hawaii. He also has served as academic vice president of the University of Hawaii statewide system.

I personally know of no scientist in the Nation who is better qualified to comment upon the Department of Energy's research program in renewable energy. Moreover, he is a personal friend of mine who has supported me in my campaigns for election and reelection. Now where can you find a man as qualified as he is? So I take great pleasure in presenting Dr. John Shupe, director of the Hawaii Natural Energy Institute.

Dr. Shupe, I will be more than happy to listen to you.

STATEMENT OF DR. JOHN W. SHUPE, DIRECTOR, HAWAII NATURAL ENERGY INSTITUTE, UNIVERSITY OF HAWAII

Dr. Shupe. Thank you, Mr. Chairman, for that very generous introduction.

As you have indicated, I have been involved in the development of renewable energy resources for more than a decade, having closely followed the patterns of funding for the renewables during this period, and I am deeply concerned with the severe reduction in support from more than $750 million in 1980 to less than $100 million in 1984 in the administrative budget request and feel it is not in the best interest of this Nation's energy future. This drastic erosion in funding is totally inconsistent with DOE's stated guidelines on long-term, high-risk R&D and the policy of keeping all energy options open as was enunciated earlier this year at an energy conference in Hawaii by the Honorable James McClure.

The majority of the solar and renewable advocates take no issue with this rational approach. Certainly I endorse it. Our concern is with the interpretation and implementation of this policy.

The steep downward trend in support for the renewables reflects the accepted conventional wisdom that renewable energy alternatives are exotic 21st century technologies. Unfortunately, this could become a self-fulfilling prophecy, for without adequate support and incentives, only limited market penetration will be achieved with these alternatives by the year 2000. The progress made to date in Hawaii and throughout the United States in moving many of the renewable energy resources toward commercialization should help to dispel this myth. I will limit my testimony to our experiences in Hawaii, but similar successes with a variety of renewable alternatives have been made nationwide.

Hawaii has both the incentive and the opportunity to develop renewable resources as substitutes for petroleum. The incentive lies in the fact that over 90 percent of our energy comes from imported oil, two-thirds of which is foreign crude. The opportunity is provided by the diversity and the abundance of Hawaii's indigenous energy resources. A partial inventory of ongoing renewable energy projects and applications in Hawaii follows.

Bagasse, the fibrous residue remaining after sugarcane is processed, serves as boiler fuel to provide nearly 8 percent of the total energy demands in the State, for an annual savings in imported oil of $100 million.

In 1982, 64 percent of the electricity generated on the Island of Oahu was produced from nonfossil fuel, of which 73 percent was from bagasse and 27 percent from hydroelectric power—20,000 watts.

Solar collector systems provide annual savings in imported oil of $7 million.

A 3-megawatt geothermal powerplant generates electricity for the big island grid.

A 200 kilowatt windmill located on Oahu has been the host subject for a wind turbine in the NASA/DOE testing program, and more than 100 small wind generators dot the Hawaiian landscape; mini OTEC operated in Hawaii's waters and successfully demonstrated the ocean thermal energy conversion or OTEC concept. A $17 million study has begun on the feasibility of connecting the known geothermal resources with the major energy market on Oahu through the installation of submarine electric cable.

From these various projects, an appreciable infrastructure for the development of renewables has emerged involving the full cooperation of all segments of the public and private sectors, as illustrated by the development of geothermal energy in Hawaii.

From 1972 to 1981, a total of $13.4 million was spent on exploratory surveys, well drilling, and construction of geothermal powerplants. The Federal Government provided $10.8 million of these funds and $2.4 million came from the State. With a limited market for energy on the big island and the risk of drilling in a rift zone of an active volcano, it was difficult to identify private venture capital. Once the validity of the resource was established, however, the private sector has already committed many times in the amount of public development costs, in moving the resource toward full commercialization. Ultimately many hundreds of millions of dollars in private capital will be invested in geothermal power for energy-intensive industry on Hawaii and for transport by undersea cable to Oahu. Although $13 million of public funds is a significant expenditure, without it we would still be wondering today if geothermal resources exist in Hawaii, and therein lies much of our concern regarding the Federal retreat on funding for the renewables. Is it premature?

Hawaii feels that their resources must experience the same preferential period of support and incentives that was granted to conventional energy supply sources during their infancy. Well over $200 billion of Federal subsidy and tax relief has gone into the development of conventional energy systems, running all the way from the depletion allowance to nuclear fuel reprocessing. It is totally unrealistic to insist that the renewables become cost competitive immediately with established energy systems, most of which are still receiving various forms of subsidy.

Congress must exercise continued vigilance to assure that no further cuts are imposed. On the contrary, this downward funding trend must be reversed. With the distribution of 1984 R&D support for solar and geothermal extending across all the major technologies, including ocean energy, which is just beginning to show promise for commercialization, it would be shortsighted to terminate the OTEC option before the feasibility of this technology is defined. Many foreign nations are exhibiting interest in it, and it would be a travesty if OTEC becomes another example of the United States losing its leadership role in the final commercialization and marketing of a promising technology for which we have provided essentially all of the research and development support.

Other areas which should be flagged for funding include, one, hydrogen, for which Senate bill 2964 introduced by the chairman to establish an expanded R&D program to accelerate introduction of hydrogen technology is timely; second, advanced batteries to provide lightweight power packages for vehicles and for application in storage systems which could improve the stability of the utility grid supplied with intermittent energy sources such as wind; and three, thermochemical conversion and biomass to liquid fuels. Pyrolysis and gasification are more efficient than fermentation and anerobic digestion, and therefore have greater potential for meeting future liquid fuel demand.

In summary, the philosophy that all energy options should remain open is a sound concept on which to base the Federal energy program. When the price of oil begins to escalate again, and it will, and public opinion continues to block the orderly development of nuclear power, and it may, and the dual impacts of acid rain and the greenhouse effect become better defined, with the mounting global energy use of fossil fuels, this Nation will be remiss if we have allowed the momentum and the infrastructure that has been generated in the development of renewable energy resources to collapse.

Congress must not sanction the foreclosure of the renewable energy options.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Shupe follows:]

FEDERAL SUPPORT FOR RENEWABLE ENERGY

Testimony Presented Before

U.S. SENATE SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

BY

John W. Shupe*

My name is John Shupe. I am Director of the Hawaii Natural Energy Institute of the University of Hawaii. Since the late 1960s I have been involved in the development of renewable energy resources, primarily in Hawaii. During the 1977-78 academic year, I received a leave of absence from the University of Hawaii and served as the first Scientific Advisor to the Assistant Secretary of Energy Technology, Robert Thorne, when the U.S. Department of Energy (DOE) was established. Consequently, I have been a close observer and competitor for federal renewable energy funding from its early locus in NSF's RANN Program (Research Applied to National Needs), through the ERDA era (Energy Research and Development Administration), and now in DOE.

I strongly feel that the severe reduction in DOE renewable energy support from more than $750 million in 1980 to less than $100 million in the 1984 administrative budget request is not in the best interests of this nation's energy future. Therefore, I welcome the opportunity to urge the continuing support by Congress in stemming the drastic overall erosion in funding for renewable energy resources.

This plummenting level of support is totally inconsistent with the increasing impact which the renewables can make in satisfying the projected global energy demand, as well as with DOE's stated guidelines for allocating funds. These long-term, high-risk R&D guidelines and the policy of keeping all energy options open were enunciated earlier this year at an energy conference in Hawaii in the excellent keynote address presented by the Chairman of the Senate Committee on Energy and Natural Resources, the Honorable James McClure. The majority of the solar and geothermal advocates take no issue with this rational approach; certainly I endorse it. Our concern is with the interpretation and implementation of this policy, as reflected in the funding pattern for the renewables in recent years.

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*Director, Hawaii Natural Energy Institute, University of Hawaii

This steep downward trend reflects the "accepted conventional wisdom" that renewable energy alternatives are exotic 21st Century technologies with little potential for helping to meet the anticipated energy shortfall in the final decade of this century. Unfortunately, this could become a self-fulfilling prophecy, for without adequate support and incentives, only limited market penetration will be achieved with these alternatives by year 2000. The progress made to date in Hawaii and throughout the U.S. in moving many of the renewable energy resources toward commercialization should help dispel this myth. I will limit my testimony to our experiences in Hawaii, but similar successes with a variety of renewable alternatives have been made nationwide.

Hawaii has both the incentive and the opportunity to develop renewable resources as substitutes for petroleum. The incentive lies in the fact that 91.4% of our energy comes from imported oil--two-thirds of which is foreign crude. The opportunity is provided by the diversity and the abundance of Hawaii's indigenous energy resources: a) A high incidence of solar radiation; b) Steady trade winds; c) Many varieties of biomass, grown both on land and in the sea; d) A large thermal gradient between the sun-warmed ocean surface and cold deep-ocean water; and e) High temperature geothermal resources. Research was initiated well over a decade ago for developing these potential energy alternatives. The two global energy shortfalls added impetus to this effort, as Hawaii's primary energy supply became progressively more expensive and less secure with each Middle East crisis.

A comprehensive report, entitled "Energy Self-Sufficiency for Hawaii" from the June 11, 1982 issue of Science, is appended. A summary and update of this article, listing a partial inventory of on-going renewable energy projects and applications in Hawaii follows:

- There are over 20,000 flat-plate solar collector systems providing hot water for home and commercial use in Hawaii, resulting in annual savings in imported oil of nearly $7 million.
- There are three rooftop photovoltaic (PV) demonstration projects on Oahu and Molokai and a major PV system providing electricity and hot water for the Wilcox Hospital on Kauai, both funded by DOE; and more than 250 home owners throughout the State who have installed PV electric systems--both with and without storage.
- The State Department of Planning and Economic Development (DPED) has funded a design study for a salt-gradient solar pond to provide electricity for the Natural Energy Laboratory of Hawaii.
- The three major saltwater OTEC (ocean thermal energy conversion) projects conducted in the United States (the Mini-OTEC, the Ocean Energy Converter, and the construction of the Seacoast Test Faciltiy) have all taken place in Hawaii.
- The only significant source of cold deep-ocean water anywhere in the world suitable for OTEC-related corrosion, biofouling, system component, and aquaculture testing is available at the Seacoast Test Facility of the Natural Energy Laboratory of Hawaii.
- Both of the design studies funded by DOE for a 40 MW OTEC power plant have been sited on Oahu.
- There are more than 100 small wind generators--0.2 to 50 kW--with a total capacity of around 2000 kW dotting the Hawaiian landscape, most of which were privately funded.
- The MOD-OA 200 kW windmill located at Kahuku on the North Shore of Oahu has generated more than twice as much power during each year of its operation than that of any of the other three MOD-OAs located in New Mexico, Rhode Island, and Puerto Rico.
- On the basis of the outstanding performance record of the MOD-OA, Hawaiian Electric Company has entered into agreement with General Electric for the installation of a huge wind turbine (in the 7.5 MW range) at the existing MOD-OA site, and ultimately will locate a major wind farm in the Kahuku Hills area.
- Bagasse--the fibrous residue remaining after sugar cane is processed--currently provides 7 percent of the total energy demand in the State at an annual savings in imported oil of nearly $100 million.

- In 1982, 64% of the electricity distributed through the utility grid of Kauai Electric Company for its 41,000 customers was produced from non-fossil fuel, of which 73% was from bagasse and 27% from hydroelectric power.

- The BioEnergy Corporation is in the third year of a major five-year DOE funded farm demonstration program on the Big Island on fast-growing strains of eucalyptus; smaller test plots of both eucalyptus and leucaena are being located on all of the major islands by University of Hawaii scientists in cooperation with local interests.

- Pacific Resources, Inc. has the lead in another DOE project on the feasibility of a hydropyrolysis process for converting high-yield cellulosic crops to liquid fuels.

- A 3 MW geothermal power plant is feeding electricity into the Big Island grid, giving Hawaii the distinction of becoming the second state in the union, after California, to generate electricity from its geothermal resources.

- Three major private consortia (Amfac-Thermal Power-Dillingham Corp., Barnwell-GEDCO, and True Ventures-Campbell Estate) are in various stages of planning, permitting, and drilling for geothermal resources on the Big Island of Hawaii.

- Both Hawaii Electric Light Company and Maui Electric Company have released Requests for Proposals to the private sector for the design of geothermal power plants.

- Similarly, both the City and County of Honolulu and Maui County have released requests for design bids on resource recovery of municipal solid waste, including the conversion of the bulk of this "urban ore" to energy.

- There is a fleet of forty electric vehicles on Oahu (25 at Hawaiian Telephone Company and 15 at the Hawaii Natural Energy Institute) to study the possible use of electric vehicles as future replacement for oil-fueled ground transportation in Hawaii.

- Hawaiian Electric Company has announced an agreement with DOE for the initial phase of a $16.6 million study on the feasibility of connecting the known geothermal resource of the Big Island with the primary energy market on Oahu, through the installation of a high voltage submarine electric cable.

This representative sample of renewable energy projects illustrates the diversity and depth of interest that have been generated in Hawaii over the past decade in seeking indigenous alternatives to imported oil. An appreciable infrastructure for the development of these resources has been established with the full cooperation of all segments of the public and private sectors, including State and County governments, the University, the electric utilities of the four major islands, the technical and business communities, and citizen groups. A crucial factor has been the strong level of support from the federal energy agency, most recently the Department of Energy. A close and productive interaction has developed both with DOE Washington and with the San Francisco Operations Office, which administers much of the project support. An additional asset has been the interest and initiative provided by Hawaii's able congressional delegation. Senator Spark Matsunaga of the Committee on Energy and Natural Resources, Senator Daniel Inouye, and Representatives Daniel Akaka and Cecil Heftel all have been most active in supporting renewable energy.

I will present one brief case study to illustrate how these various groups and their respective support contribute to a successful project. In 1972, well before the energy crisis, the Hawaii State Legislature, in response to a request by the University, appropriated $200,000 for geothermal research--contingent upon matching federal funds. The University obtained a $254,000 grant from NSF, and the project got underway. During the next eight years, a total of $13.4 million was spent in completing the exploratory surveys, drilling a well to 6450-foot depth, testing and analyzing the geothermal steam, and constructing a 3 MW power plant. $10.8 million of these funds were provided by the federal government (NSF, ERDA, DOE), $2.4 million from the State and County of Hawaii, and only $200,000 from the private sector. With the limited market for energy on the Big Island, plus the uncertainty of finding a commercial geothermal resource, and the additional risk of drilling in the rift zone of an active volcano, it was difficult to identify private venture capital.

Once the validity of the resource was established with public funds, however, the private sector--as represented by three development consortia--has already committed many times the amount of public development costs in moving the resource toward full commercialization. Ultimately, many hundreds of millions of dollars in private capital will be invested in the development of geothermal power to provide electricity for energy-intensive industry on Hawaii and/or for transport by undersea cable to the primary energy market on Oahu. Although $13.2 million of public funds is a significant expenditure, without it we would still be wondering today if geothermal resources exist in Hawaii.

And therein lies much of our concern regarding the federal retreat on funding for the renewables--is it premature? Hawaii feels that these resources must experience the same preferential period of support and incentives that was granted to conventional energy supply sources during their infancy. A Battelle study a few years ago estimated that more than $200 billion of federal subsidy and tax relief had gone into the development of these conventional energy systems--coal, oil, natural gas, nuclear power--running all the way from depletion allowances to nuclear fuel reprocessing and radioactive waste disposal. It is totally unrealistic to insist that the renewables become cost-competitive immediately with established energy systems, most of which are still receiving various forms of subsidy. It is also totally unrealistic to assume that society can function satisfactorily on this Earth for many more decades with total dependence on existing energy supply sources.

While commending the foresight of Congress in salvaging some level of support for the renewables, which currently stands at less than a third of the $750 million 1980 figure, I would strongly urge that continued vigilance be exercised to assure that no further cuts are imposed. On the contrary, serious consideration should be directed to reversing the downward trend in support for renewable resources back up to a level commensurate with the potential of these indigenous alternatives to contribute to the future global energy supply. A 1984 budget for the renewables, equivalent to the 1982 level, would be an appropriate start.

The distribution of this R&D support for solar and other renewables should extend across all of the major solar and geothermal alternatives, including ocean energy. Significant amounts of public and private investment have gone into the development of OTEC, which is beginning to show promise for commercialization. It would be short-sighted to terminate the OTEC option before the feasibility of this technology is better defined, not only for generating electricity but also for producing fertilizer, methanol, hydrogen, and fresh water and in aquaculture applications. France, the Netherlands, Japan, Taiwan, India, and the Soviet Union have all shown varying degrees of interest in OTEC development. It would be a travesty if OTEC becomes another example of the U.S. losing its leadership role in the final commercialization and marketing of a promising technology for which we have provided essentially all of the research and development support.

Other promising areas that should be flagged for funding include those relating to the storage and transport of intermittent energy sources. One technology which falls in the long-range, high-risk category is hydrogen, which has tremendous potential for diminishing this nation's dependence on imported oil. Unfortunately, while many European nations, Canada, and Japan are beginning to acknowledge this potential through increased R&D support, the U.S. in recent years has actually reduced funding for hydrogen research. The passage of S.2964, a bill introduced by Senator Spark Matsunaga to establish an expanded research and development program to accelerate the introduction of the hydrogen economy, would be timely in reversing the levels of interest and support for this neglected technology.

Another neglected area is advanced battery R&D. As recently as three years ago the national energy laboratories were projecting commercial prototypes of aluminum-air and other advanced batteries within this decade, but now work on these promising options has been virtually phased out. An improved battery for vehicles would permit the design of a power package which would be much lighter than the present lead-acid battery system, and would still provide a vehicle with the handling characteristics and driving range similar to internal combustion engines. Another application of these batteries would be in storage systems which could improve the stability of utility grids supplied with significant amounts of intermittent energy, such as wind or photovoltaics.

A final example of a declining budget for a key technology is the support of basic research on the thermochemical conversion of biomass to liquid fuels--another long-term, high-risk technology. Of the various technologies available for biomass conversion (fermentation, anaerobic digestion, pyrolysis, and gasification), only the thermochemical processes (pyrolysis and gasification) are sufficiently efficient to have the potential of making a significant contribution to future liquid fuel demands--and essentially all support for basic research on these processes has been terminated.

In summary, the philosophy that all reasonable energy options should remain open is a sound concept upon which to base the federal energy program. When the price of oil begins to escalate again--and it will; as public opinion continues to block the orderly development of nuclear power--and it may; and as the dual impacts of acid rain and the greenhouse effect become better defined with the mounting global energy use of fossil fuels, this nation will be remiss if we have allowed the momentum and the infrastructure that has been generated in the development of renewable energy resources to collapse. Congress must not sanction the foreclosure of the renewable energy options.

Thank you, Mr. Chairman, for the opportunity to appear before this Subcommittee.

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Energy Self-Sufficiency for Hawaii

John W. Shupe

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Energy Self-Sufficiency for Hawaii

John W. Shupe

Summary. Currently, Hawaii is almost totally dependent for energy on imported oil. The island state has a wide variety of renewable energy resources, however, and for the past decade has supported the development of these resources as substitutes for seaborne petroleum. Sufficient progress has been made to date in commercializing a number of these alternative energy sources to give cause for optimism that Hawaii will be able to achieve energy self-sufficiency with its indigenous renewable resources.

Hawaii shares with many other isolated regions the problem of identifying a secure and affordable supply of energy. Through the middle half of this century, most of the energy-deficient regions, including Hawaii, have increasingly depended on cheap and abundant imported petroleum to satisfy their escalating energy demands. However, as imported oil has become progressively more expensive and less secure, greater effort has been directed in Hawaii to conserve energy and to develop indigenous energy resources.

The benefits of energy self-sufficiency, as they are related to the future economic well-being of Hawaii, are recognized by its citizens. The vulnerability of this island state has been demonstrated by severe maritime strikes, which have tied up essentially all shipping from the mainland United States, as well as by the 1973 oil embargo and resulting energy shortfall. Each incident reinforces the resolve to strive toward greater independence from imported commodities. Although Hawaii's renewable energy alternatives in general are both capital-intensive and fairly expensive, a number of them already appear to be cost-effective by comparison with imported oil in a life-cycle analysis.

One obvious benefit of achieving full or near-total self-sufficiency with renewable energy resources is that a secured indigenous energy supply would provide protection from both short- and long-term fluctuations in the global energy market. This stability would have a positive effect on the general economy by assuring reliable, competitively priced energy to the local consumer and by helping to attract and retain energy-intensive industry, such as the refining of manganese nodules from the Central Pacific. In addition, Hawaii's renewable alternatives are less polluting than conventional energy supplies (oil, coal, and nuclear power) and are compatible with the state's concern for the quality of the environment. The development of an indigenous energy supply also represents a major potential growth industry for Hawaii—one that would help retain a portion of the $1 billion a year currently spent on oil imported into the state and would broaden the job and tax bases.

In recognition of the risks involved in continued dependence on imported oil and the benefits to be achieved from energy self-sufficiency, a major program for the development of renewable energy resources has been under way throughout the state during the past decade. This article describes the progress made to date in Hawaii in commercializing substitutes for imported oil.

Current Energy Demand and Supply Data

The state of Hawaii consists of the eight southernmost islands in the Hawaiian Archipelago, an island chain stretching across 600 kilometers of the Central Pacific and separated from the mainland United States by nearly 4000 kilometers of ocean. These islands are the tops of shield volcanoes rising from the ocean floor and are too recent in origin to have experienced the natural cycle necessary for the formation of fossil fuels. Hawaii has a resident population of about 965,000 and a de facto population of slightly over 1,100,000 when visitors to the islands are included (*1*). Nearly 80 percent of the resident population and most of the industrial and government infrastructure are concentrated on the island of Oahu, the site of the state capital, Honolulu. By contrast to this major metropolitan area with a high-density energy demand, most of the other islands have widely dispersed low-density energy requirements, similar to many of the less developed areas throughout the world.

The total civilian energy consumption for Hawaii in 1979 was 211 trillion Btu's, which is equivalent to about 37 million barrels of oil. Figure 1 compares energy utilization in Hawaii with that of the mainland United States (*2*). The energy consumption patterns for the state and the nation differ appreciably, largely because of (i) the absence of a space heating requirement in the subtropical climate of Hawaii and (ii) the huge amount of aviation fuel necessary to service the state's tourist industry. A significant point to consider in planning for Hawaii's energy future is that nearly 60 percent of the state's current energy demand is for liquid fuels to satisfy transportation requirements.

There is some variation in the cost of energy between the separate islands, particularly with respect to electricity, for which larger generating units are more economical. At present, the price of residential electricity varies from 11.4 cents per kilowatt-hour in Honolulu to more than 19 cents per kilowatt-hour on Molokai—one of the highest electricity rates in the United States. Regular gasoline costs about 41 cents per liter ($1.55 per gallon) on Oahu, including local and federal taxes, and about 5 cents a gallon more on the other islands. Although this is higher than mainland charges for gasoline, it is still a bargain in comparison to most worldwide figures.

Currently, Hawaii is probably the most vulnerable of the 50 states to dislocations in the global oil market. It has no known fossil fuel reserves on any of its islands and no offshore oil. There is no coal coming into the state by rail, no natural gas by pipeline. The energy demand on its utilities is too small to warrant nuclear power plants, and Hawaii is not tied into a regional grid so that it can share electric loads with adjacent states. As yet, its separate islands are not even connected by a common electric grid.

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More than 90 percent of Hawaii's existing energy supply is seaborne petroleum. This virtual dependence would be of somewhat less concern if most of this import originated within the United States. Unfortunately, the reverse is true: 62.5 percent arrives directly from foreign sources—Saudi Arabia, Oman, Indonesia, and Malaysia (2). Alaska supplies 13.5 percent and the mainland 24 percent. However, the last figure is misleading, since products from mainland refineries may also be of foreign origin. Therefore, as much as two-thirds of the petroleum imported into Hawaii today comes from foreign crude.

Bagasse, the fibrous residue remaining after sucrose is squeezed from sugarcane, is the second largest source of energy for Hawaii. Nearly 2.4 million metric tons of bagasse are burned each year in the boilers of the sugar companies, providing more than 7 percent of the total energy demand of the state. Other forms of biomass are also beginning to receive slight use for boiler fuel: cane trash (leaves and tops), pineapple waste, wood chips, macadamia nutshells, and hay. The final energy supply source for Hawaii—also developed entirely by the sugar industry—is hydroelectric power, which provides slightly less than 1 percent of the total energy demand.

Renewable Energy Resources

Hawaii's nearly total dependence on seaborne petroleum is a paradox, since the state has a variety and abundance of renewable energy resources. Research was initiated more than a decade ago on the utilization of these resources as alternatives or substitutes for imported oil (3), and the energy shortfall of 1973 added impetus to the effort. To date, the impact of renewable energy resources on Hawaii's oil imports has been slight, except for the existing 8 percent input from the bagasse and hydroelectric power plants. However, the great amount of research, development, and demonstration (RD&D) that has been directed to indigenous energy sources in recent years is beginning to have positive results. Table 1 shows the origin of the $65 million spent on renewable energy RD&D in Hawaii during the past decade and the general categories in which these funds were expended (4). In the following sections I will describe the progress that has been made in moving each of Hawaii's major energy alternatives toward commercialization.

Direct solar radiation. The principal Hawaiian Islands lie between 19° and 22°N. At Honolulu the midsummer sun is 3° north of vertical, while the winter low is 45° above the southern horizon. Therefore, Hawaii has both a higher average insolation rate and a smaller seasonal variation than the mainland United States. Average annual insolation values in excess of 500 langleys (calories per square centimeter) per day are not unusual (5). Consequently, Hawaii is well suited for the utilization of all types of direct solar radiation conversion systems.

Table 1. Funding of renewable energy RD&D in Hawaii: 1971 to 1980.

Program	Source of funding (thousands of dollars)			
	Federal	State/ county	Private	Total
Ocean thermal	22,006	3,246	1,712	26,964
Geothermal	12,336	2,173	4,334	18,843
Insolation, wind, and hydro	9,437	1,494	423	11,354
Bioconversion	1,848	1,498	766	4,112
Other	1,026	2,674	256	3,956
Total	46,653	11,085	7,491	65,229

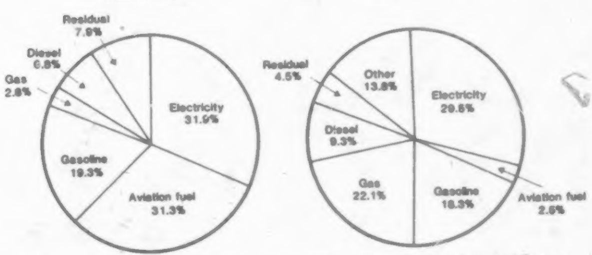

Fig. 1. Comparison of energy consumption patterns in Hawaii and the United States.

Almost 40 percent of the residential energy consumed in the state is used for heating water. This represents a good target for solar water heaters, and at present there are about 19,000 flat-plate solar collectors installed in Hawaii, resulting in annual savings in imported oil of about $6 million. Depending on the hot water requirements of the family and insolation levels at the location of the dwelling, the investment for an average solar water heater can be amortized in 3 to 7 years at the current rate of state and federal tax incentives.

Where higher temperatures are required, solar thermal systems with concentrating collectors show excellent potential, both for process heat and for generating electricity. Three major design studies on solar thermal systems for utility and industrial applications in Hawaii, involving parabolic collectors with both dish and trough configurations, have been funded by the U.S. Department of Energy (DOE). Preliminary design studies have been conducted as well on solar ponds. The state is reviewing a proposal from Jet Propulsion Laboratory to design and construct a 500-kW salt-gradient solar pond to supply electricity to the Natural Energy Laboratory of Hawaii on the Kona Coast of the Big Island of Hawaii.

Photovoltaic power systems utilizing solid-state semiconductor devices to convert solar radiation directly into electricity are beginning to find limited application in Hawaii. A photovoltaic system that generates 35 kW of electricity for Wilcox General Hospital on Kauai was completed in December 1981. This concentrating dual system consists of a series of parabolic troughs that focus radiation on the solar cells. Water, which is warmed as it circulates through the system and cools the cells, provides much of the hospital's hot water.

Three small photovoltaic systems—2 to 3.5 kW—have also been installed on homes in Hawaii as demonstration projects of the DOE to provide operational data on the performance of photovoltaic units for meeting the requirements of three average families in Hawaii. These roof-mounted systems are metered into the utility grid, and records are kept of the amount of surplus electricity from the photovoltaic system that is fed back into the utility grid so that it can serve as a credit against utility electricity charges. In addition to these three demonstration projects, more than 250 homeowners in Hawaii have installed photovoltaic systems—both with and without storage—to help meet their electrical needs.

Ocean energy systems. The ocean is an excellent solar collector and storage system. A century ago, the French scientist Jacques d'Arsonval discovered that the temperature difference between the sun-warmed ocean surface and the cold deep-ocean water can be used to generate electricity. Unlike many other renewable resources, which provide energy intermittently, there is negligible cooling of the ocean at night, so that ocean thermal energy conversion (OTEC) could be utilized for 24-hour base-load power.

Figure 2 shows a preliminary inventory of locations throughout the state with some potential for OTEC systems, but additional bathymetric and ocean current studies are required to verify that these sites are suitable for OTEC plants. There is an economic advantage if a site is located near shore, since the umbilical cable for transmitting electricity from a floating OTEC power plant to a shore-based utility grid would be both shorter and simpler in design. There is also some interest in constructing shore-based OTEC plants, with the cold-water pipe running out through the surf zone. Hawaii has a number of sites that satisfy criteria for both nearshore floating and shore-based OTEC power plants.

In addition to OTEC power plants feeding electricity into an island utility grid, floating anchored platforms and untethered grazing OTEC plants could be utilized to produce ammonia or hydrogen as a synthetic fuel. Craven (6) estimated that within the 200-mile zone of the islands constituting the Hawaiian Archipelago, it is possible to produce 10 to 15 quads (1 quad = 10^{15} Btu's) per year of OTEC power—an amount of energy greater than that derived from the current annual import of oil by the United States.

Three significant saltwater OTEC projects have been located in Hawaii. Mini-OTEC was the first fully operational closed-cycle OTEC system to generate electricity from the ocean thermal gradient. It was a joint venture of the Lockheed Missile and Space Company, the Dillingham Corporation, and the state of Hawaii to demonstrate the technical feasibility of an OTEC power plant.

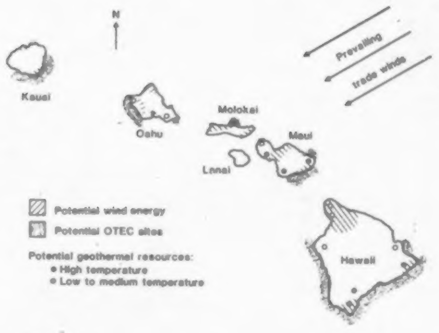

Fig. 2. Inventory of potential wind, OTEC, and geothermal resources in Hawaii.

The heat exchangers and other components of Mini-OTEC were located on a barge (Fig. 3), and a polyethylene pipe 61 centimeters in diameter suspended from a buoy was used to bring up cold water from a depth of 655 meters. During its 4-month deployment off Hawaii in late 1979, Mini-OTEC generated slightly over 50 kW of electricity, of which 35 to 40 kW was used internally to drive the system and 10 to 15 kW was net power.

The second project located in Hawaii was OTEC-1, which represented a major effort of the DOE to obtain operational data on the components of a 1-megawatt OTEC system. More than $50 million went into the project, most of which was spent in the mainland United States to convert a Navy tanker to accommodate the massive heat exchangers and other components for circulating deep-ocean water through the system at 246,000 liters per minute. The *Ocean Energy Converter* was deployed 25 km off the coast of Hawaii in early 1981, and 3 months of excellent operational data were obtained before budget limitations caused premature termination of the program.

The third major OTEC project is the Seacoast Test Facility (STF), located at the Natural Energy Laboratory on the Big Island of Hawaii. The STF was designed to provide a permanent shore-based facility from which to conduct reliable, economical, long-range test programs on biofouling, corrosion, and component performance. The advantage of this site is that the ocean floor drops off abruptly from the shoreline, so that a depth of 640 m can be reached by extending a pipeline 1860 m from the laboratory, through the surf zone, and along the ocean floor. Phase 1 of the STF has been completed and includes the installation of a 30-cm cold-water pipe with a

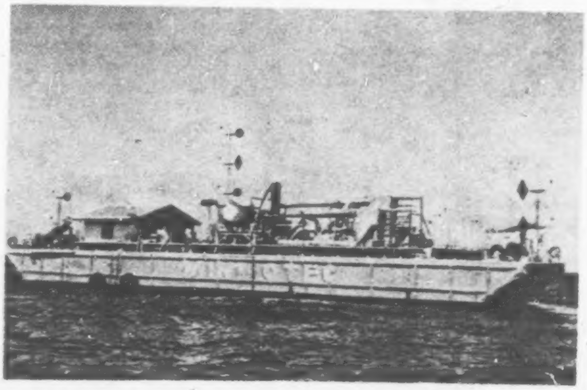

Fig. 3. Mini-OTEC, an ocean thermal energy conversion demonstration system deployed off Hawaii in 1979.

flow capacity of 5700 liters per minute. Current warm-water capability is 7600 liters per minute. It is likely that the warm- and cold-water capacities will be increased by a factor of 10 by the end of 1982.

Hawaii is interested in OTEC not only for base-load power but also for the probable spin-off in aquaculture and desalination from the cold, nutrient-rich, deep-ocean water. Since DOE funding for OTEC may be curtailed in the future, Hawaii is looking both to industry and to foreign governments as potential customers for conducting research with the unique cold-water capability of the STF. However, the immediate outlook for continuing OTEC activity in Hawaii was reinforced by the DOE announcement on 19 February 1982 that two of the nine proposals for conducting the conceptual design phase for a closed-cycle OTEC pilot plant had been approved for funding, each at $900,000. Both these proposals are based on OTEC sites located on Oahu.

Biomass resources. The major agricultural crop of Hawaii is sugarcane. Nearly 1 million metric tons of raw sugar are produced annually on 89,000 hectares of prime agricultural land (*2*). Major byproducts are 2.4 million metric tons of bagasse and 280,000 metric tons of molasses. The moisture content of bagasse is about 48 percent, and it is an excellent boiler fuel, replacing nearly 2.5 million barrels of imported oil a year. Although molasses is a satisfactory feedstock for ethanol production, the economics of conversion still appear to be marginal, so that most of the molasses is used as cattle feed. Even if all of the molasses produced in the state were converted to ethanol and used as transportation fuel, it would not have a major impact on the amount of gasoline required. The ultimate potential for ethanol from molasses is about 87 million liters a year—only 8 percent of the current fuel used for automobiles in Hawaii.

Forest products also have excellent energy potential in Hawaii, both as boiler fuel and as feedstock for liquid fuels. Most of the 650,000 ha of forest lands in Hawaii are natural stands, from which forestry thinning operations are providing a limited source of wood chips for sugar company boilers. Different varieties of eucalyptus and the giant koa haole (leucaena) seem to show promise for tree farms in Hawaii, and an extensive study of the cultivation and harvesting requirements of several of these varieties has been conducted to determine the amount and location of land appropriate for tree farming with each of these strains (*7*).

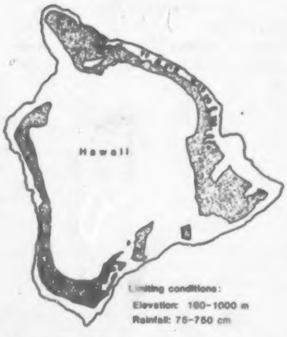

Fig. 4. Potential resource area for *Eucalyptus grandis*.

Figure 4 shows the potential growth area identified for *Eucalyptus grandis* on the Big Island of Hawaii. Similar figures have been completed on promising varieties of trees for each of the major islands, resulting in an overall inventory of land in the state with good potential for tree farming.

There are numerous projects and programs under way in Hawaii for expanding the energy role of biomass. The sugar industry has established a task force to investigate sugarcane as a total energy crop, with the sugar considered as either a by-product or a feedstock for liquid fuels. Row and stalk spacing; growth period; the use of irrigation, fertilizers, and desiccants; and genetic breeding to maximize bulk yield are under review.

Tree farming is also receiving a great deal of attention, with the Hawaii Division of Forestry providing $500,000 annually for the planting of 1 million seedlings a year for energy tree farms throughout the state. The BioEnergy Corporation is conducting a 5-year demonstration program on fast-growing strains of eucalyptus, which will be harvested in 5 to 7 years. Studies on leucaena (*8*) show that a model farm of 405 ha with 4,100,000 leucaena trees would replace 22,000 barrels of diesel fuel each year, about one-third of Molokai's annual electric energy need. Pacific Resources, Inc., is leading a DOE-funded project on the feasibility of a hydropyrolysis process for converting a variety of Hawaii's high-yield cellulosic crops to liquid fuels.

Other biomass projects are addressing (i) more effective use of pineapple waste for boiler fuel, particularly on Molokai, and (ii) growth in seawater of single-cell algae, which convert sunlight and nutrients to lipids rather than cellulose. The algae project is jointly funded by the state and the Solar Energy Research Institute and has achieved high mass densities in a 50-m^2 algal raceway (*9*), as shown in Fig. 5. The generation of both lipids and protein by this process looks sufficiently promising to justify increasing the project to a 40,500-m^2 system.

Wind energy. The northeast trade winds, which blow across Hawaii approximately three-quarters of the time, constitute one of the most consistent and reliable wind patterns in the world (*10*). This favorable wind regime is reinforced by the terrain of the islands and a fairly stable inversion layer at an altitude of around 1800 m. These factors combine to give a funneling effect: as the trade winds are forced up and over the mountain ranges and around the islands, their velocity is greatly increased—often more than doubled.

Each of the major islands in the state has good sites for wind development, as illustrated in Fig. 2. A refinement of the wind energy data for Molokai and Maui, both of which have excellent wind regimes, is shown in Fig. 6. In addition to the favorable wind patterns, there is no icing in Hawaii to contribute to overloading and vibration of windmill blades, while hurricanes and high-gusting winds are extremely rare in this area of the Pacific. Except for the corrosive effects of moist salt-laden air, which can be handled through proper design, Hawaii has an ideal combination of physical and climatic conditions for the introduction of wind power.

There are about 70 small wind generators—0.2 to 50 kW—dotting the Hawaiian landscape, most funded privately. To date, there is only one large windmill in Hawaii—a 200-kW wind turbine generator located at Kahuku on the north shore of Oahu (Fig. 7). The Hawaiian Electric Company (HECO) was one of four utilities selected by the Department of Energy to receive this MOD-OA wind generator for demonstration purposes. During its first year of operation, ending 3 July 1981, this windmill generated 870,970 kWh, far more electricity than any of the other MOD-OA's, located in New Mexico, Rhode Island, and Puerto Rico, have generated during any year.

HECO is optimistic about the future of wind power for Hawaii and has entered into a contract with Windfarms, Inc., for the purchase of 80 MW of electricity from wind turbine generators to be located near the 200-kW unit at Kahuku. Windfarms will finance these huge wind turbines at an estimated total cost of

$350 million, taking advantage of all available tax incentives and write-offs. HECO will not have to identify investment capital to purchase the generating equipment, but will buy the electricity from Windfarms for distribution through the utility grid. The system should be completed by the end of 1984, at which time it will provide nearly 10 percent of Oahu's electricity demand, saving about 600,000 barrels of imported oil a year.

Geothermal resources. Initial geological and geophysical explorations for geothermal resources were conducted in 1973 on the Big Island of Hawaii, which has two active volcanoes and a complex rift zone system. The first successful experimental well was drilled in Hawaii in 1976 to a depth of 1967 m. Preliminary flashing (Fig. 8) and flowing of the well were encouraging (*11*), and subsequent testing verified that this is one of the hottest geothermal wells in the world, with a 358°C downhole temperature. In addition, the quality of the fluid is excellent, with low levels of toxic materials and of components which precipitate out to clog the circulation and generation system.

A broader resource assessment program, consisting of the compilation and evaluation of readily accessible geological, geochemical, and geophysical data both on the island of Hawaii and throughout the island chain, identified 20 regions in 13 general areas with some potential for geothermal development (*12*). These areas are shown in Fig. 2, where the solid dots represent areas where temperatures are probably sufficiently high to generate electricity and the open dots represent lower temperature resources, which could be used to supply process heat for industrial applications. Unfortunately, there are no high-temperature geothermal resources on Oahu, where more than 80 percent of the state's population base and electricity market are located.

A 3-MW geothermal wellhead generator was installed at the well shown in Fig. 8, and when it first began generating electricity in August 1981, Hawaii became the second state to generate electricity from its geothermal resources. Compared to California's 900 MW of installed geothermal capacity, this 3-MW power plant is a very modest beginning. However, with 20 potential geothermal regions identified and the possibility of an interisland electric cable, geothermal power in Hawaii could approach the current capacity in California by the end of this century. Three drilling consortia have been established, and Hawaii's first successful geothermal well drilled entirely with private capital was flashed in October 1981. HECO has revised its plans to construct more fossil-fired power plants on the Big Island and has issued a request for proposal on a 25-MW geothermal power plant—to be the forerunner of commercial development for this major geothermal field.

Fig. 5. Algal production raceway of the University of Hawaii.

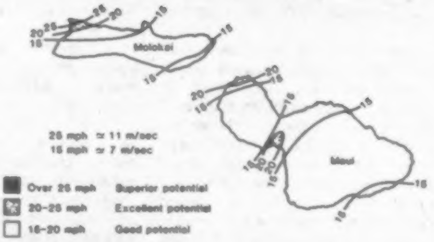

Fig. 6. Average annual wind speeds for Maui and Molokai.

Fig. 7. Windmill at Kahuku, Oahu, operated by the Hawaiian Electric Company.

Fig. 8. Flow test of geothermal well at Puna, Hawaii.

Summary of Hawaii's renewable energy resources. The development of most of Hawaii's energy alternatives will in no way be limited by the magnitude of the resource base. The total capacity of all of the possible onshore and nearshore OTEC power plants exceeds the projected base-load electrical demands of the state many times over, as does the potential geothermal resource. It is estimated that the Puna area of the island of Hawaii alone may provide 3000 MW-centuries of generating capacity from its geothermal reservoirs (*2*). Similarly, during trade wind conditions, the potential wind energy in the state exceeds by a factor of 10 Hawaii's total electrical needs (*10*). Until and unless an economic method for storing wind energy is developed, the factor limiting commercialization of wind energy is the total amount of wind power that can be accommodated by the utility grid.

The availability of suitable land area could limit extensive utilization of both direct solar radiation systems and biomass growth for boiler fuel farms or liquid fuel feedstock. However, since the ultimate energy supply mix for Hawaii will probably include a variety of indigenous energy resources, each maximized to satisfy an end use of direct heat, electricity, or fuel, no single renewable resource is likely to be dominant. In fact, the other extreme will probably be the case. As cost-competitive energy systems are developed for the renewables, additional energy markets will be required to make effective use of these energy alternatives. Eventually, Hawaii should be able to reverse its role of near-total dependence on imported oil to one of energy self-sufficiency.

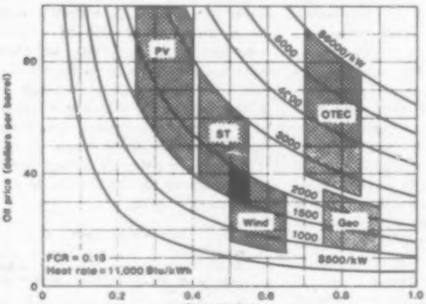

Fig. 9 Fuel displacement by renewable energy systems for capacity factors based on Hawaiian conditions.

Table 2. Electrical energy potential of renewable resources in Hawaii.

Technology	Commercialization	Base, intermediate, or peak load	Capital costs (1980 dollars per kilowatt)		Resource potential by 2000 (MW)
			1985	2000	
Geothermal	Near term	Base	2000	1200	1000
OTEC	1990 to 1995	Base	8000	2600	1600
Solar thermal and photovoltaics	1990 to 1995	Intermediate (interrupted)	3000 8000	2000 2000	1800
Wind	Near term	All three (interrupted)	1500	700	450
Biomass	Near term	All three	1500	1500	160
Hydroelectric	Near term	All three	800	800	100
Municipal solid waste	1985	All three	2200	2200	45

Table 3. Electricity supply for Hawaii in 2005 based on three projected future cases.

Source	Amount (million kilowatt hours)		
	Baseline case	Savings case	High oil cost case
Geothermal	5,684	5,339	5,306
OTEC	3,568	2,521	2,758
Wind	2,314	2,074	2,016
Solar thermal	1,120	974	1,967
Bagasse	860	860	860
Municipal waste	276	276	276
Hydroelectric	98	98	98
Photovoltaics	Negligible	Negligible	204
Oil	3,621	1,058	923
Total	17,541	13,200	14,408

Energy Future

Energy is a crucial element in planning for the state's economic future. However, it is difficult to predict with any degree of certainty what Hawaii's energy supply sources will be in the years ahead, since many of the key factors influencing the rate of penetration of the renewables into the energy market are independent of any actions and decisions that will take place within the state. Included among these factors are the continuing availability and the pricing of Middle East oil, the discovery and accessibility of new oil reserves throughout the world, the degree to which coal and nuclear power are developed in the future, the national energy policy on support and incentives for renewable energy, and improvements that may occur in alternative energy systems which will accelerate their acceptance in the energy market.

Extensive reviews and projections of Hawaii's energy supply and demand have been conducted throughout the past decade, both inside and outside the state. Easily the most comprehensive study was a 3-year, $550,000 joint effort by the DOE and the state to establish data bases and integrated energy analyses from which to develop scenarios for alternative energy futures. This was a collaborative effort of Lawrence Berkeley Laboratory and Hawaii's Department of Planning and Economic Development which resulted in the six-volume Hawaii Integrated Energy Assessment (HIEA) (*2*), covering the state's total energy picture. Table 2 is taken from the HIEA study and summarizes parameters related to the potential of the various renewable energy resources for satisfying a portion of Hawaii's electrical demand. Included are estimates of when commercialization of the technology is expected in Hawaii; whether the resource is suitable for base (24 hours), intermediate, or peak (2 to 3 hours) load; the capital cost range from 1985 to 2000, in 1980 dollars per installed kilowatt; and the maximum potential of the resource by the year 2000. It should be recognized that Table 2 summarizes electrical energy potential only. Although there may be a slight shift by the end of this century from liquid fuels to electricity, the major supply problem for Hawaii over the next two decades will be transportation fuel for both surface and air travel.

A convenient method for obtaining a rough estimate of how high the price of oil must go before the various renewable alternatives become cost competitive on the basis of fuel replacement alone has been developed by Weingart (*13*). Figure 9 illustrates the fuel replacement worth of five renewable resources: photovoltaics (PV), solar thermal (ST), wind, OTEC, and geothermal. Biomass would show up on Fig. 9 in about the same place as geothermal. The curves in Fig. 9 were computed on a fixed charge rate (FCR) of 18 percent and a heat conversion rate of 11,000 Btu's per kilowatt-hour. The capacity factor estimates are based on Hawaiian conditions, which explains the optimistic projection that windmills will generate power 50 to 65 percent of the time.

Even as a rough approximation, it is apparent from Fig. 9 that wind and geothermal (also biomass) are already cost-competitive as fuel replacements. If oil prices exceed $40 a barrel, the other alternatives also show economic benefit. In addition, for resources such as geothermal and OTEC, which can provide base-load power and satisfy capacity requirements of the utility, a greater allowance should be made for replacing new capacity at the margin.

Three scenarios for future energy demand in Hawaii are presented in the HIEA (2). All three are based on the state's "most likely" projection of population and personal income and on the assumption that the mandated automobile mileage standards will be implemented. All three of these demand forecasts are predicated on oil continuing to be the predominant energy supply. Therefore, these forecasts serve only as a starting point for an analysis of the role of renewables in Hawaii's energy future and how they will affect the projected demand, both for oil and for total energy.

In the first scenario, the baseline case, it is assumed that there will be a 3 percent per year escalation in the world oil price above the general inflation rate, starting with $30 a barrel in 1980. The second scenario, the savings case, is similar to the baseline case, but in addition to improved automobile mileage it is assumed that other conservation practices are instituted, mainly increased efficiency in appliances, lighting, water heating, and space conditioning. The third scenario, the high oil price case, is based on a 10 percent per year increase in oil price above the inflation rate, which could occur if there were major disruptions in global oil production. Table 3 lists forecasts for the contribution that the major energy supply sources will make in meeting total electricity demand for the state in 2005. Forecasts are presented for each of the three scenarios.

Table 3 projects a relatively high level of penetration of the renewables for electricity generation by 2005, with the baseline case showing 79 percent penetration and the high cost case 94 percent. However, since HIEA assumes that there will be very little replacement of liquid fuels by electricity during the next two decades and that jet fuel demand will increase by 68 percent over the next 25 years, the amount of the total energy provided by the renewables in 2005 is only 37 percent for the baseline case and 46 percent for the high cost case. These forecasts seem somewhat conservative. My own projections are that 50 percent electrical self-sufficiency by 1990 and 50 percent total energy self-sufficiency by 2000 represent an achievable goal for Hawaii.

There has been sufficient progress in Hawaii in laying the groundwork for converting from oil to renewable energy that the current reduction in federal support for renewable energy RD&D, while representing a severe setback, should not be fatal. Geothermal, wind, direct solar radiation, and various forms of biomass are already cost-competitive with imported oil in Hawaii, and other energy alternatives are fast approaching commercialization. The utilities, the sugar industry, the lending institutions, and other elements of the private sector have become active participants in the development of these alternatives to imported oil. An endowed chair in renewable energy resources was established recently at the University of Hawaii by an $800,000 grant from Coral Industries, Inc., of Honolulu. Both state and county governments are committed to the effort to commercialize renewables and will endeavor to provide a favorable political environment in which it can proceed. Therefore, the appreciable momentum that has been building over the past decade, in conjunction with the anticipated long-range price increases for conventional energy supplies, should assure continuing progress in the development of Hawaii's energy alternatives.

While an optimum energy program for any region must be unique and site-specific, the experience gained in Hawaii in the development of its renewable energy resources may have positive spin-off to other areas deficient in conventional energy supplies. The excellent physical resources and well-defined boundary conditions of an island state will facilitate rapid evaluation of the feasibility of these new technologies. The rate and level of penetration achieved by Hawaii with its renewable energy alternatives may help provide some insight to other regions on the potential of their indigenous resources for contributing to a rational energy future.

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Senator **Matsunaga**. Thank you very much, Dr. Shupe. I will have a few questions which I will submit in writing for response for the record, but in order to save time I will not put the questions to you at this time, and we will now revert to the regular schedule and the initial panel which has two Californians on it.

Panel No. 1 nuclear programs, will the members of that panel come forward to the witness table, please? Mr. Richard L. Grant, president of the Boeing Engineering & Construction Southeast, Inc., Oak Ridge, Tenn.; Mr. D. L. Broussard, vice president, Arizona Public Service Co., Phoenix, Ariz., the chairman of the Gas-Cooled Reactor Associates Management Committee, San Diego, Calif.; Mr. Harold M. Agnew, president, GA Technologies, Inc., Washington, D.C.; Mr. R. B. Richards, general manager of Advanced Reactor Systems Department, General Electric Co., Sunnyvale, Calif.; and Dr. J. L. Shohet, chairman, University Fusion Association, professor of electrical and computer engineering, the University of Wisconsin, Madison, Wis.—so will you then begin, Mr. Grant?

STATEMENT OF RICHARD L. GRANT, PRESIDENT, BOEING ENGINEERING & CONSTRUCTION SOUTHEAST, INC.

Mr. **Grant**. Certainly; thank you, sir. Mr. Chairman, I appreciate this opportunity to talk to you this morning. Dr. Shupe and I have served on a few international panels together on biomass and that sort of thing, and I can also attest to his expertise and my privilege at having served with him.

Today, though, I am here to talk about what I consider to be one of the most exciting high technology programs in the DOE's repertoire, and that is the uranium enrichment program. My company, Boeing Engineering & Construction Southeast, became involved in this program in the early seventies when the private sector enrichment was being investigated as a possible way to proceed.

It has evolved now to where we have constructed a factory and R&D facility at Oak Ridge, Tenn., for the purpose of manufacturing centrifuge machines. The factory is in operation today and has been since September 1981. It has produced 200 of the so-called set III-type centrifuge uranium enrichment. As it stands today, it has 450 people at work in it and about 1,000 people at work in our subcontractor vender network.

In 1990 when the program is at its peak production capability we will have about 1,750 people in that factory and about 3,500 at work in our supplier vender network. That is just Boeing's part of the operation. There are two other people involved in that—Goodyear and Garrett—as well.

Boeing built and is operating this factory in Oak Ridge, Tenn., because we believe that the centrifuge program and the net process for uranium enrichment makes sense for the United States. It makes sense because it can in fact decouple the process from the cost of energy, specifically the price of electricity. It does so by consuming 95 percent less electricity than does the current process of gaseous diffusion as practiced by the Department of Energy in Oak Ridge, Tenn., and Portsmouth, Ohio.

No other process in industry in the world has the capability to decouple itself so completely from the cost of energy, and that is a very big plus. Electricity alone for one SWU unit of enriched uranium as currently done by the gaseous diffusion process costs $78 in 1983 dollars. For the centrifuge it costs $2—a very large difference. The decoupling is illustrated by the fact that an electricity increase in cost which would add $10 to the cost of a diffusion SWU unit would add $44 cents to the cost of a centrifuge SWU unit. The total operating and maintenance costs of centrifuge SWU today comes to about $35 as compared to something over $100 for gaseous diffusion.

The other numbers that people hear are because of the way we choose to treat cost of capital which is an added cost that is calculated into the cost of the SWU. It should be noted, however, that not 1 cent of money has been borrowed to support the centrifuge program or any other enrichment enterprise for that matter. None has been borrowed and none has been appropriated from tax moneys. Every cent of the $2,127,845 that has been appropriated for the centrifuge program has been pay-as-you-go basis, pay as you go from the standpoint of both domestic and foreign utilities, and in fact one-third of that amount has come from the foreign utilities.

The U.S. uranium enrichment enterprise is entering an era at present where economic conditions in the world have made our failure to implement centrifuge technology at an earlier date for us into an uncompetitive cost competition with our foreign competitors. This world marketplace also suffers from an oversupply situation today, and if the United States intends to stay in this marketplace, and there are many compelling reasons why we should, then it is imperative that we get on with the placing of the new high technology, low-cost systems for enrichment of uranium. By that mechanism our price will be lower than our competition. It will stay lower, and will increase only a fraction of what our competitors do over time.

As a practical matter, it is demonstrated and certain that we can place the set III centrifuge as it now exists. It is also reasonable to assume that the new technologies that are set IV and set V will be successful. Prototype scale machines of this design are currently in operation at our facility in Oak Ridge and delay in getting emplacement of this would cost a lot of money because of the difference in the cost as I stated earlier, $35 versus $100. For example, a 3-year delay would cost us the loss of about 6.6 million SWU of centrifuge production, which equates to $429 million—a difference of $65 per SWU.

In addition to that, any loss of the manufacturing process learning process by which a factory is well designed and decreases the cost of each subsequent unit which it builds would add cost to the new machine that is subsequently emplaced.

In the meantime, the Union Carbide folks and Lawrence Livermore Laboratory have been working on the Atomic Vapor Laser Isotope Separation process which having only demonstrated minute quantites shows promise of a system which may ultimately use no more energy than centrifuge, may require less capital, and may be able to strip uranium tails to lower levels.

Attached to my formal testimony is an assessment of a number of cases—19 to be specific—that take into account I think all possible variations of new technologies for the future for the next 25 years. These assessments are done without adding the cost of capital or interest to them so that we can make selections from among them as to what the best approach might be.

Senator **Domenici** [presiding]. Mr. Chairman, could I interrupt for a moment?

First, I thank the Senator from Hawaii for presiding. I am in a position where I can only stay for 10 minutes and have to take the bill up on the floor. We hope to have a Senator that will come and take over, but if we can't, we will just have to put the statements in the record. I would greatly appreciate it if each of you would consider your written testimony to be part of the record and take no more than 5 minutes in an oral discussion with the committee. We just can't do it any differently, and I apologize for that.

Mr. **Grant**. I will terminate this very quickly.

Senator **Domenici**. I appreciate that.

Mr. **Grant**. I suggest the scenario in my written testimony, a scenario that I think keeps all our options open and provides us with a hedge against the uncertainty of successful development of new technology both in terms of time and success.

Under no circumstances, however, must we—we must not proceed under any circumstances on a campaign which does other than minimize the amount of gaseous diffusion per SWU that is accomplished over the next few years. That is the one way we know for sure that we will not be competitive.

Thank you very much.

[The prepared statement of Mr. Grant follows:]

STATEMENT OF
RICHARD L. GRANT, PRESIDENT
BOEING ENGINEERING AND CONSTRUCTION SOUTHEAST, INC.
BEFORE THE ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
MAY 3, 1983

Mr. Chairman, Distinguished Members of the Subcommittee:

My name is Richard L. Grant; I am President of The Boeing Company's subsidiary, Boeing Engineering and Construction Southeast, Inc. I thank you for this opportunity to describe one of the most exciting high technology programs in the United States today - the Uranium Enrichment Program of the Department of Energy.

My company's involvement in Uranium Enrichment began with interest in private sector enrichment in the early 1970s and has evolved to the construction of a new manufacturing facility in Oak Ridge, Tennessee which started production operations in September 1981. This factory was built and equipped with $65 million of Boeing funds. It was built for the sole purpose of fabrication, assembly and test of gas centrifuges and R&D for advanced centrifuges. It has now completed and delivered nearly 200 centrifuges of the type called Set III. It is operating at its design production rate and is demonstrating the performance intended in well-designed manufacturing systems, i.e., reduction of cost with each successive unit manufactured. It has proven that the total estimated cost of centrifuges for the Portsmouth Gas Centrifuge Enrichment Plant (GCEP) can be met if the production lines are not disrupted. Nearly 450 people are at work in the Boeing facilities in Oak Ridge and more than 1000 at suppliers and vendors. When maximum production rate is achieved in 1990, about 1750 people will be at work in the Boeing facilities and about 3500 at suppliers and vendors.

Boeing built and is operating this facility because we believe that the centrifuge process for uranium enrichment makes sense for the United States. It will reduce the cost and therefore the price of enriched uranium. Most importantly it will decouple the price of enriched services from the cost of electricity for all intents and purposes. Specifically it reduces energy consumption by 95 percent from that of the existing gaseous diffusion. No other process industry in the world has the technology to decouple its product so completely from the cost of energy as does Centrifuge Uranium Enrichment. At today's cost of power, the electricity for one SWU unit of enrichment by the existing gaseous diffusion process cost about $78 compared to about $2 by GCEP. An electricity cost increase which adds $10 to the cost of a diffusion SWU adds only about 44 cents to the cost of a centrifuge SWU. If electricity costs escalate a total of only 4 percent per year for the next ten years (over the past 10 years it has averaged 17 to 18 percent), the electricity cost for diffusion will increase by $33 compared with $1.00 for GCEP. The total operating and maintenance cost, including electricity, for a centrifuge SWU is less than $35 compared to over $100 for gaseous diffusion at today's costs. Other numbers which you hear, such as the $115 price per SWU in 1983 dollars for centrifuge, are the result of how we choose to treat the cost of capital. It should be noted that no money has been borrowed nor appropriated from tax monies for the centrifuge program. Every cent of the $2,127,845,000 appropriated through FY 1983 has been on a pay-as-you-go basis with the cost being borne by utilities both domestic and foreign. About one-third of this amount has come from foreign utilities.

The U.S. Uranium Enrichment enterprise is now entering an era in world economic conditions where our failure to implement the centrifuge technology earlier has resulted in our enrichment services being non-competitive in the world marketplace while also being faced with an oversupply situation. If the United States intends to stay in this marketplace, and there are many compelling reasons why we must, then it is imperative that we get on with emplacing the new high-technology systems. If we do so, the U.S. price will be lower, will stay lower, and will increase only a fraction of that of our competitors with time.

As a practical matter, it is demonstrated and certain that we can emplace the Set III Centrifuge and expect the predicted performance and reliability. It is similarly reasonable to expect that the extensions of centrifuge technology dubbed Set IV and Set V will be successful. Prototype scale rotors using the Set V materials are running on uranium hexaflouride gas in Boeing facilities in Oak Ridge right now, and about three-fourths of the Set IV improved machine output has been demonstrated elsewhere. Although these improved centrifuges will out produce the current Set III machines, a significant cost advantage will be lost if we stop producing these very good machines to wait for even better ones. For example, assume that Set III production were halted today and Set V production started in 1988. The delay of the first two process buildings of GCEP would result in a loss of at least three years or 6.6 million SWU of centrifuge production. With the difference in operating cost of Diffusion and Centrifuge at about $65/SWU, the net additional cost of production associated with delay would be $429 million. In addition, the front-end learning benefit from factory production would be lost with a halt of Set III and would have to be restarted with initiation of production of the advanced technology centrifuges. This disruption is estimated to cost about $110 million more than would continued production of Set III.

Meanwhile, work conducted by Union Carbide and the Lawrence Livermore Laboratory on the Atomic Vapor Laser Isotope Separation process, while having demonstrated only minute quantities of separative work, shows promise of a system which may ultimately use no more energy than the centrifuge, may require less capital and may be able to strip uranium tails to lower levels than centrifuge. Its real capability, however, remains to be proven while the centrifuge process has hundreds of thousands of hours of machine operation and thousands of kilograms of enriched uranium behind it.

The attachment provides an assessment of 19 cases using various strategies for bringing new technology on line for production.

The technical maturity of each of the elements of the long-range enrichment program suggests a rational, cost-effective and risk-minimizing scenario which should be pursued by the United States Enrichment enterprise:

1) Continued Set III machine manufacturing so that the ability to produce low-cost machines is retained along with the ability to produce at increased rates in the future if improved centrifuges and AVLIS do not develop as currently projected.
2) Accelerate Set IV and/or Set V Advanced Gas Centrifuge development activities toward earliest practical high-confidence production readiness - FY 1987-88.
3) Continue a thorough AVLIS Technology Development program toward complete demonstration - FY 1988-89.

This scenario provides Set III machines required to fill the first centrifuge process building, nearing readiness at this time. It also provides a limited quantity of Set III machines for the second process building and an orderly transition to Set IV and/or Set V in the centrifuge manufacturing program. The remainder of the second process building can be filled with Set IV or Set V machines and spares of these designs will be available for replacement in the first process building as the Set III machines wear out. Meanwhile, underground, foundation and structural work should proceed for future process buildings in the FY 1987-88 timeframe as insurance against the failure or delay of AVLIS. In FY 1988-89, a competent decision can be made as to what quantity of the Set V centrifuge capacity is needed in light of the degree and pace of AVLIS success at that time. This scenario keeps the options open to produce at higher rates at any appropriate point, and allows for some uncertainty in the development time for the evolving technologies.

In any case, this scenario will provide a high-confidence assurance that the United States will enter the 1990s with the best and lowest cost Uranium Enrichment capacity.

We have the right and best technology in the world ready for implementation. Our lead on the foreign competition will increase even further as we refine existing centrifuge capability and if AVLIS is successful. It would, however, be a mistake to follow a path which does not reduce reliance on gaseous diffusion to an absolute minimum for the future. We know for sure that such reliance will make the United States non-competitive.

I thank you for your time and attention. I'll be pleased to try to answer any questions you may have.

Attachment to United States Senate
Energy Research and Development
Subcommittee Testimony - May 3, 1983

ASSESSMENT OF URANIUM ENRICHMENT SCENARIOS - CENTRIFUGE AND AVLIS UTILIZATION

April 1983

INTRODUCTION

The following analyses are intended to present comparisons of various future scenarios for the U.S. Uranium Enrichment Enterprise which while covering a wide range of possible approaches, makes no specific predictions of the future in terms of either the market for enriched uranium nor the economic climate variables. They encompass nearly all possible scenarios for emplacing the Gas Centrifuge Enrichment Plant (GCEP) and/or the Atomic Vapor Laser Isotope Separation (AVLIS) technology. Each case except Case 19, minimizes the production of separative work by the Gaseous Diffusion Process (GDP), since it is clear that the enterprise costs can not be reduced by production of more GDP SWUs. Case 19 presents a nominal production case where the entire quantity is produced by GDP.

Cases Examined

A series of 19 cases were examined which range from production by GDP, GCEP and AVLIS together or singly using existing schedules for GCEP and AVLIS. For each case, it is assumed that the entire output capability of GCEP and/or AVLIS is produced. Each case is described in the following pages.

Cost and Schedule Data

Cost data was derived directly from DOE and Lawrence Livermore Labs data as were the schedules for production capacity. The schedules for adding Set V incremental process buildings beyond the first eight was derived from that of Buildings 6, 7 and 8. The accelerated AVLIS schedule of Cases 13 and 17 assume that work can proceed in parallel. The Appendix shows the details of each scenario for Production. Table 1 shows all of the cost data utilized. All cost figures are in FY 1984 dollars.

Production Scenarios

All the scenarios considered, each anticipate 25 years of future market for enriched uranium. Near-term demand is assumed to be relatively small. Scenarios were included which set the near-term demand for production at 15 million SWUs per year and 10 million SWUs per year, followed by production at whatever level the new technologies can provide as a function of time. Cases were also included where no gaseous diffusion SWUs are produced and all available capacity is derived from the new technologies together or singly. Figures 1 through 4 show the time histories of production for these scenarios. Each of these figures show the remaining production by gaseous diffusion.

Production/Cost Summaries

Tables 2 through 5 show the total production and costs for each case summarized from the Appendix and the case descriptions. The costs are all treated in two ways: 1) All capital costs, prior year sunk capital costs, all remaining development costs and the production costs are summed to the total enterprise cost, 2) All sunk costs are forgiven. The total enterprise costs for each case vary, in part, because they produce different quantities of enriched product. Therefore, the most important cost for comparison is the average cost per SWU over the enterprise duration. The average cost per SWU is also shown on Tables 2 through 5 both with and without sunk costs included. Each case also notes the last year which GDP would operate.

CONCLUSIONS

1. The lowest total enterprise costs always result from use of the Set V GCEP.

2. Set III GCEP plus AVLIS provides lower average SWU cost than if it is cancelled in favor of AVLIS unless all sunk costs are forgiven.

3. Set IV GCEP plus AVLIS provides lower average SWU costs in all cases than AVLIS alone.

4. The lowest total enterprise cost and the lowest average SWU cost result from SET V GCEP alone for all scenarios.

5. When the largest quantity scenarios are used, Set V GCEP plus AVLIS is slightly lower cost per SWU, than the moderate quantity scenarios for Set V alone and significantly lower than AVLIS alone.

6. Cancellation of GCEP will result in higher cost SWUs.

7. Set V Development will result in lowest possible costs.

DESCRIPTION OF CASES

Case 1

Using 15 million annual SWU minimum requirements, the Set III GCEP is completed and AVLIS develops and is brought on-line as currently projected out through 27 million annual SWU capacity. The case is summarized as follows:

	GDP	Set III	AVLIS	TOTAL
TOTAL SWU PRODUCTION	112.1M	158.9M	296M	567M
PRODUCTION COST	$ 10.3B	$ 4.6B	$ 6.5B	$ 21.4B

Total Cost:	Production	$21.4B
	CIP/CUP	2.5B
	GCEP Cap.	7.5B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$35.1B

AVERAGE COST PER SWU = $61.90

Case 2

Same as Case 1 except Set IV Centrifuges are used:

	GDP	Set IV	AVLIS	TOTAL
TOTAL SWU PRODUCTION	107.2M	231.1M	296M	634.3M
PRODUCTION COST	$ 9.9B	$ 4.4B	$ 6.5B	$ 20.8B

Total Cost:	Production	20.8B
	CIP/CUP	2.5B
	GCEP Cap.	7.5B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$34.5B

AVERAGE COST PER SWU = $54.39

Case 3

Same as Cases 1 and 2, except Set V Centrifuges are used:

	GDP	SET V	AVLIS	TOTAL
TOTAL SWU PRODUCTION	95.6M	455.2M	296M	846.8M
PRODUCTION COST	$ 8.8B	$ 4.1B	$ 6.5B	$19.4B

Total Cost:	Production	$19.4B
	CIP/CUP	2.5B
	GCEP Cap.	7.8B
	Set V Devel	0.4B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$33.8B

AVERAGE COST PER SWU = $39.91

Case 4

Using 15 million annual SWU minimum requirement, assume that AVLIS is either unsuccessful or is cancelled and Set V centrifuges are used in GCEP:

	GDP	SET V	TOTAL	
TOTAL SWU PRODUCTION	96.6M	455.2M	551.8M	
PRODUCTION COST	$ 8.9B	$ 4.1B	$13.0B	

Total cost:	Production	$13.0B
	CIP/CUP	2.5B
	GCEP Cap.	7.8B
	Set V Devel.	0.4B
	Total	$ 23.7B

AVERAGE COST PER SWU = $42.95

Case 5

Using 15 million annual SWU minimum requirement, assume that centrifuge is cancelled in FY 1984 and only AVLIS is used along with gaseous diffusion:

	GDP	AVLIS	TOTAL	
TOTAL SWU PRODUCTION	148M	296M	444M	
PRODUCTION COST	$13.6B	$6.5B	$20.1B	

Total Cost:	Production	$ 20.1B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$ 28.9B

AVERAGE COST PER SWU = $65.09

Case 6

Using 10 million annual SWU minimum requirement, with same new technology production scenario as Case 1:

	GDP	SET III	AVLIS	TOTAL
TOTAL SWU PRODUCTION	65.3M	158.9M	296M	520.2M
PRODUCTION COST	$6.0B	$ 4.6B	$ 6.5B	$17.1B

Total cost:	Production	$ 17.1B
	CIP/CUP	2.5B
	GCEP Cap.	7.5B
	AVLIS Cap.	2.7B
	AVLIS Devel	1.0B
	Total	$30.8B

AVERAGE COST PER SWU = $59.21

Case 7

Same as Case 6 except Set IV Centrifuges used:

	GDP	SET IV	AVLIS	TOTAL
TOTAL SWU PRODUCTION	63.8M	231.1M	296M	520.9M
PRODUCTION COST	$5.9B	$4.1B	$6.5B	$16.5B

Total Cost:	Production	$16.5B
	CIP/CUP	2.5B
	GCEP Cap.	7.5B
	AVLIS Cap	2.7B
	AVLIS Devel.	1.0B
	Total	$ 30.2B

AVERAGE COST PER SWU = $51.11

Case 8

Same as Cases 6 and 7 except Set V centrifuges used:

	GDP	SET V	AVLIS	TOTAL
TOTAL SWU PRODUCTION	57.0M	455.2M	296M	808.2M
PRODUCTION COST	$5.2B	$4.1B	$6.5B	$15.8B

Total Cost:	Production	$15.8B
	CIP/CUP	2.5B
	GCEP Cap.	7.8B
	Set V Devel	0.4B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$ 30.2B

AVERAGE COST PER SWU = . . . $37.37

Case 9

Using 10 million SWU annual minimum requirement, assume that AVLIS is either unsuccessful or cancelled and Set V centrifuges used in GCEP:

	GDP	SET V	TOTAL	
TOTAL SWU PRODUCTION	57.0M	455.2M	512.2M	
PRODUCTION COST	$ 5.2B	$ 4.1B	$ 9.3B	

Total Cost:	Production	$ 9.3B
	CIP/CUP	2.5B
	GCEP Cap.	7.8B
	Set V Devel	0.4B
	Total	20.0B

AVERAGE COST PER SWU = $39.05

Case 10

Same as Case 9 except assume that Centrifuge is cancelled in FY 1984:

	GDP	AVLIS	TOTAL	
TOTAL SWU PRODUCTION	90.0M	296.0M	386.0M	
PRODUCTION COST	$ 8.3B	$6.5B	$14.8B	

Total Cost:	Production	$14.8B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	23.6B

AVERAGE COST PER SWU = $ 61.14

Case 11

Using the 10 million annual SWU minimum scenario but assumes that the maximum production capacity requirement never exceeds that of the fully powered GDP or the 8 building GCEP with Set V centrifuges. Both Set V and AVLIS development have proceeded successfully but it is decided to split the required maximum production between a 4 building Set V GCEP and AVLIS:

	GDP	SET V	AVLIS	TOTAL
TOTAL SWU PRODUCTION	57.0M	247.8M	204.8M	509.6M
PRODUCTION COST	$ 5.2B	$ 2.2B	$ 4.5B	$ 11.9B

Total Cost:	Production	$11.9B
	CIP/CUP	2.5B
	GCEP Cap.	5.4B
	Set V Devel	0.4B
	AVLIS Cap.	1.9B
	AVLIS Devel.	1.0B
	Total	$ 23.1B

AVERAGE COST PER SWU = $ 45.33

Case 12

Same as Case 11 except total maximum production is with AVLIS after cancellation of GCEP in FY 1984:

	GDP	AVLIS	TOTAL	
TOTAL SWU PRODUCTION	146.2M	363.4M	509.6M	
PRODUCTION COST	$13.5B	$ 8.0B	$ 21.5B	

Total Cost:	Production	$21.5B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap.	2.7B
	AVLIS Devel.	1.0B
	Total	$ 30.3B

AVERAGE COST PER SWU = $59.46

Case 13

Using 10 million annual SWU minimum requirement scenario but bring AVLIS on line as fast as possible for maximum production after cancellation of GCEP in FY 1984:

	GDP	AVLIS	TOTAL	
TOTAL SWU PRODUCTION	90.0M	545.0M	635.0M	
PRODUCTION COST	$ 8.3B	$12.0B	$20.3B	

Total cost:	Production	$20.3B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap.	4.1B
	AVLIS Devel.	1.0B
	Total	$ 30.5B

AVERAGE COST PER SWU = $48.03

Case 14

Using 10 million annual SWU minimum requirement scenario but add 3 buildings of Set V GCEP after cancellation of AVLIS in FY 1984:

	GDP	SET V	TOTAL	
TOTAL SWU PRODUCTION	57.0M	576.3M	633.3M	
PRODUCTION COST	$ 5.2B	$ 5.2B	$10.4B	

Total Cost:	Production	$10.4B
	CIP/CUP	2.5B
	GCEP Cap.	10.2B
	Set V Devel.	0.4B
	Total	$ 23.5B

AVERAGE COST PER SWU = $37.11

Case 15

Ignore GDP Production cancel GCEP in FY 1984 and proceed on normal AVLIS production Scenario:

	AVLIS	TOTAL		
TOTAL SWU PRODUCTION	296M	296M		
PRODUCTION COST	$6.5B	$ 6.5B		

Total Costs:	Production	$ 6.5B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap	2.7B
	AVLIS Devel.	1.0B
	Total	$ 15.3B

AVERAGE COST PER SWU = $51.69

Case 16

Ignore GDP production, cancel AVLIS in FY 1984 and proceed on normal Set V GCEP production scenario:

	SET V	TOTAL		
TOTAL SWU PRODUCTION	455.2 M	455.2M		
PRODUCTION COST	$4.1B	$4.1B		

Total costs:	Production	$ 4.1B
	CIP/CUP	2.5B
	GCEP Cap.	7.8B
	Set V Devel	0.4B
	Total	14.8B

AVERAGE COST PER SWU = $ 32.51

Case 17

Ignore GDP, cancel GCEP in FY 1984 and proceed to bring AVLIS on line as fast as possible for maximum production:

	AVLIS	TOTAL		
TOTAL SWU PRODUCTION	545 M	545 M		
PRODUCTION COST	$12.0B	$12.0B		

Total Cost:	Production	$12.0B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	AVLIS Cap.	4.1B
	AVLIS Devel	1.0B
	Total	$ 22.2B

AVERAGE COST PER SWU = $40.73

Case 18

Ignore GDP, cancel AVLIS in FY 1984 and add 3 buildings of Set V GCEP as fast as possible for maximum production:

	SET V	TOTAL		
TOTAL SWU PRODUCTION	576.3M	576.3M		
PRODUCTION COST	$ 5.2B	$ 5.2B		

Total Costs:	Production	$ 5.2B
	CIP/CUP	2.5B
	GCEP Cap.	10.2B
	Set V Devel	0.4B
	Total	$ 18.3B

AVERAGE COST PER SWU = $ 31.75

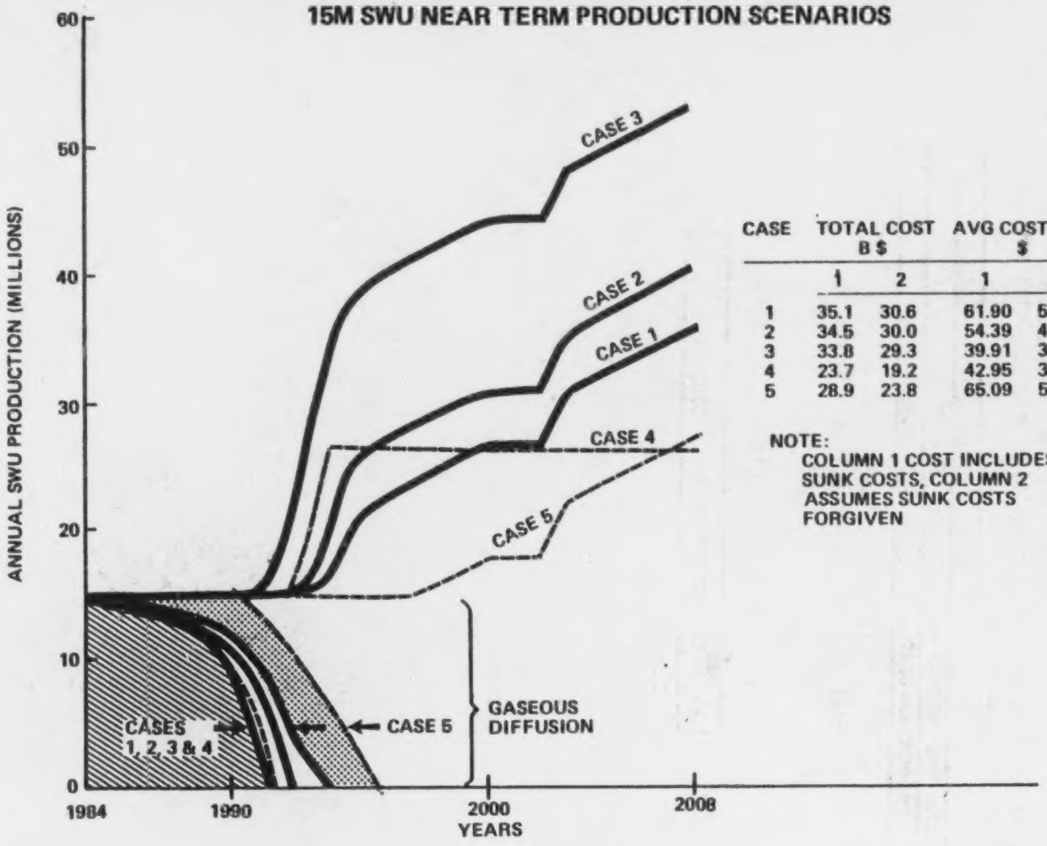
Case 19

This case uses the same production capacity as a function of time as Case 11 but assumes that the entire capacity is produced with gaseous diffusion; GCEP and AVLIS cancelled in 1984:

	GDP	TOTAL		
TOTAL SWU PRODUCTION	509.6M	509.6M		
PRODUCTION COST	$ 46.9B	$ 46.9B		

Total Cost	Production	$46.9B
	CIP/CUP	2.5B
	GCEP Sunk	2.6B
	Total	$ 52.0B

AVERAGE COST PER SWU = $102.04



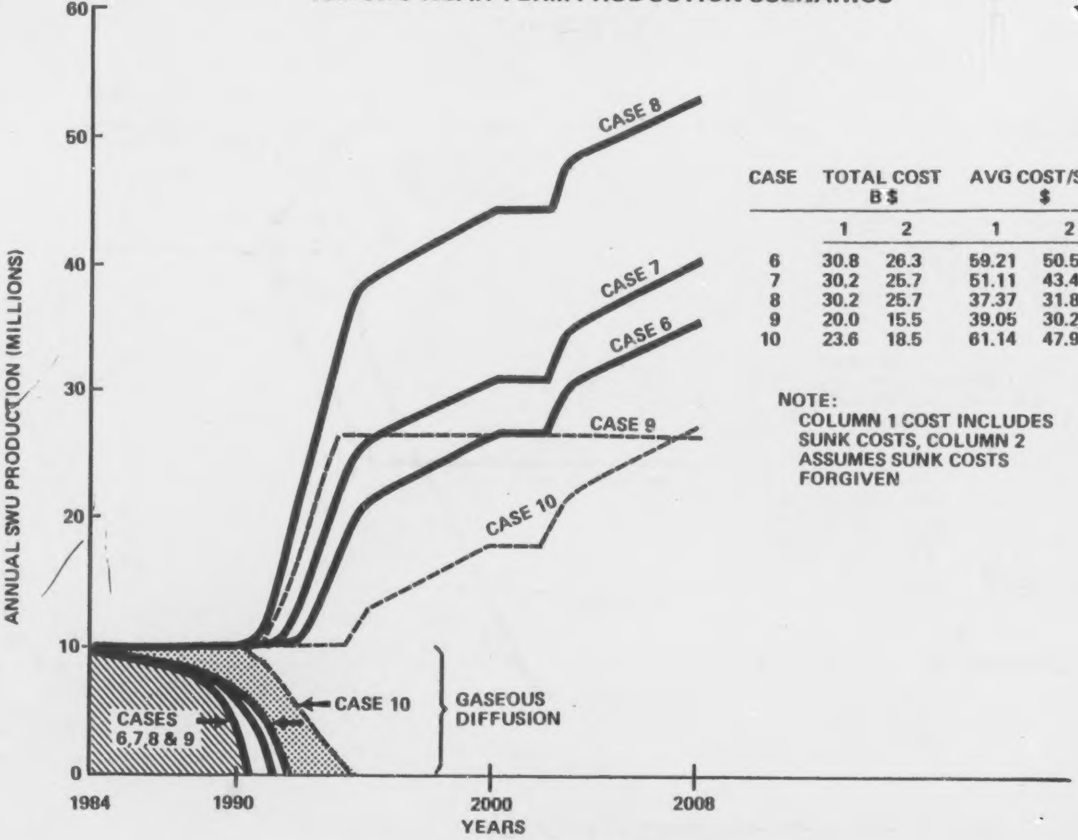
15M SWU NEAR TERM PRODUCTION SCENARIOS

CASE	TOTAL COST B $		AVG COST/SWU $	
	1	2	1	2
1	35.1	30.6	61.90	53.97
2	34.5	30.0	54.39	47.30
3	33.8	29.3	39.91	34.60
4	23.7	19.2	42.95	34.80
5	28.9	23.8	65.09	53.60

NOTE:
COLUMN 1 COST INCLUDES SUNK COSTS, COLUMN 2 ASSUMES SUNK COSTS FORGIVEN

FIGURE 1

10M SWU NEAR TERM PRODUCTION SCENARIOS

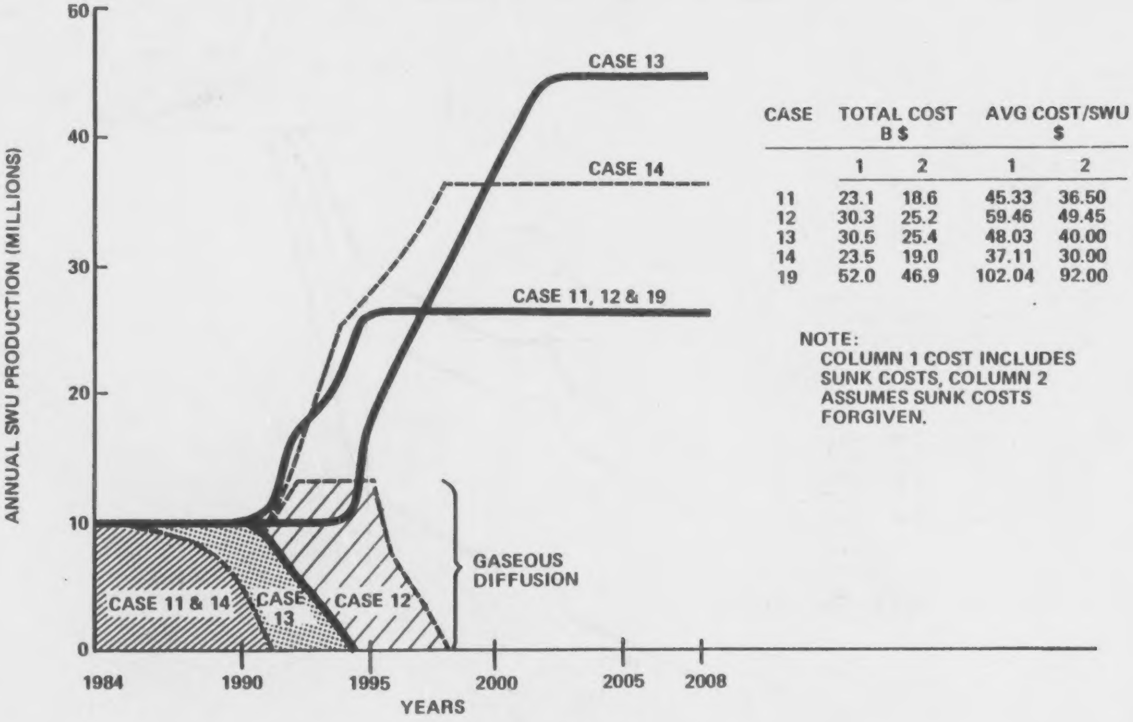


CASE	TOTAL COST B $		AVG COST/SWU $	
	1	2	1	2
6	30.8	26.3	59.21	50.56
7	30.2	25.7	51.11	43.49
8	30.2	25.7	37.37	31.80
9	20.0	15.5	39.05	30.26
10	23.6	18.5	61.14	47.93

NOTE:
COLUMN 1 COST INCLUDES SUNK COSTS, COLUMN 2 ASSUMES SUNK COSTS FORGIVEN

FIGURE 2

MODERATE NEAR TERM PRODUCTION SCENARIOS

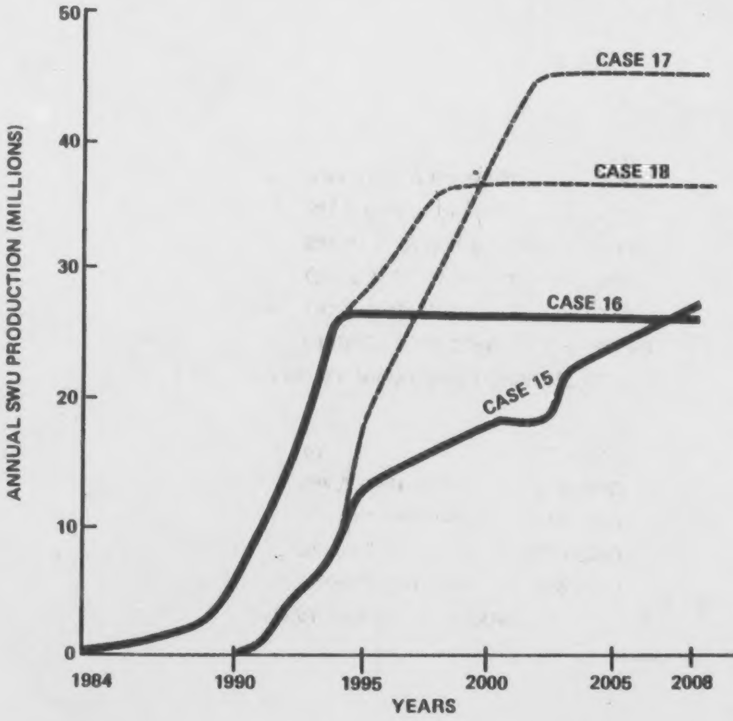


CASE	TOTAL COST B $		AVG COST/SWU $	
	1	2	1	2
11	23.1	18.6	45.33	36.50
12	30.3	25.2	59.46	49.45
13	30.5	25.4	48.03	40.00
14	23.5	19.0	37.11	30.00
19	52.0	46.9	102.04	92.00

NOTE:
COLUMN 1 COST INCLUDES SUNK COSTS, COLUMN 2 ASSUMES SUNK COSTS FORGIVEN.

FIGURE 3

NO GDP FY 1984 AND ON SCENARIOS



CASE	TOTAL COST B $		AVG COST/SWU $	
	1	2	1	2
15	15.3	10.2	51.69	34.46
16	14.8	12.3	32.51	27.02
17	22.2	17.1	40.73	31.38
18	18.3	15.8	31.75	27.42

NOTE:
COLUMN 1 COST INCLUDES SUNK COSTS, COLUMN 2 ASSUMES SUNK COSTS FORGIVEN

FIGURE 4

TABLE 1
COST DATA
(FY 1984 Dollars)

TOTAL OPERATING COSTS

Gaseous Diffusion = $92/SWU
Set III Centrifuge = $29/SWU
Set IV Centrifuge = $19/SWU
Set V Centrifuge = $ 9/SWU
AVLIS = $22/SWU

CAPITAL AND DEVELOPMENT COSTS

CIP/CUP Sunk Costs = $2.5B
GCEP Sunk Costs = 2.0B
GCEP 1984 Close Out = 0.6B
Set III & IV GCEP to go = 5.5B
Set V GCEP Add-on = 0.3B
Add 3 Set V Buildings = 2.4B

AGC Development Cost = $0.4B
AVLIS Development Cost = 1.0B
AVLIS Capital (27M SWU) = 2.7B
AVLIS Capital (13.2M SWU) = 1.9B
AVLIS Capital (45M SWU) = 4.1B

TABLE 2
15 MILLION SWU NEAR TERM PRODUCTION
(See Figure 1 for Scenarios)

CASE	PRODUCTION SOURCE	TOTAL COST B$		COST/SWU $		PRODUCTION M SWU's				LAST YEAR OF GDP
		1 *	2 *	1 *	2 *	GDP	GCEP	AVLIS	TOTAL	
1	Diffusion, Set III GCEP and normal AVLIS	35.1	30.6	61.90	53.97	112.1	158.9	296.0	567.0	1993
2	Diffusion, Set IV GCEP and normal AVLIS	34.5	30.0	54.39	47.30	107.2	231.1	296.0	634.3	1992
3	Diffusion, Set V GCEP and normal AVLIS	33.8	29.3	39.91	34.60	95.6	455.2	296.0	846.8	1991
4	Diffusion and Set V GCEP only	23.7	19.2	42.95	34.80	96.6	455.2	0	551.8	1992
5	Diffusion and normal AVLIS only	28.9	23.8	65.09	53.60	148.0	0	296.0	444.0	1996

* Column 1 is burdened with sunk costs for CIP/CUP and for cancelled GCEP where appropriate. Column 2 deletes all sunk costs.

NOTE: ALL COSTS ARE FY 1984 DOLLARS

TABLE 3
10 MILLION SWU NEAR TERM PRODUCTION
(See Figure 2 for Scerarios)

		TOTAL COST B $		COST/SWU $			PRODUCTION M SWU's			LAST YEAR OF GDP
CASE	PRODUCTION SOURCE	1 *	2*	1*	2*	GDP	GCEP	AVLIS	TOTAL	
6	Diffusion, Set III GCEP and normal AVLIS	30.8	26.3	59.21	50.56	65.3	158.9	296.0	520.2	1992
7	Diffusion, Set IV GCEP and normal AVLIS	30.2	25.7	51.11	43.49	63.8	231.1	296.0	590.9	1991
8	Diffusion, Set V GCEP and normal AVLIS	30.2	25.7	37.37	31.80	57.0	455.2	296.0	808.2	1990
9	Diffusion and Set V GCEP only	20.0	15.5	39.05	30.26	57.0	455.2	0	512.2	1990
10	Diffusion and normal AVLIS only	23.6	18.5	61.14	47.93	90.0	0	296.0	386.0	1994

* Column 1 is burdened with sunk costs for CIP/CUP and for cancelled GCEP where appropriate.
Column 2 deletes all sunk costs

NOTE: ALL COSTS ARE FY 1984 DOLLARS

TABLE 4
10 MILLION SWU NEAR TERM PRODUCTION
(See Figure 3 for Scenarios)

CASE	PRODUCTION SOURCE	TOTAL COST B $ 1 *	TOTAL COST B $ 2 *	COST/SWU $ 1 *	COST/SWU $ 2 *	PRODUCTION M SWU's GDP	PRODUCTION M SWU's GCEP	PRODUCTION M SWU's AVLIS	PRODUCTION M SWU's TOTAL	LAST YEAR OF GDP
11	Diffusion, ½ of Set V GCEP and ½ normal AVLIS	23.1	18.6	45.33	36.50	57.0	247.8	204.8	509.6	1990
12	Diffusion, No GCEP and AVLIS at same maximum capacity as Set V GCEP	30.3	25.2	59.46	49.45	146.2	0	363.4	509.6	1997
13	Diffusion, No GCEP and accelerated AVLIS	30.5	25.4	48.03	40.00	90.0	0	545.0	635.0	1994
14	Diffusion, Set V GCEP with 3 buildings added—No AVLIS	23.5	19.0	37.11	30.00	57.0	576.3	0	633.3	1990
19	Diffusion only	52.0	46.9	102.04	92.00	509.6	0	0	509.6	2008

*Column 1 is burdened with sunk costs for CIP/CUP and for cancelled GCEP where appropriate. Column 2 deletes all sunk costs.

NOTE: ALL COSTS ARE FY 1984 DOLLARS

TABLE 5
NO GDP FY 1984 AND ON
(See Figure 4 for Scenarios)

CASE	PRODUCTION SOURCE	TOTAL COST B $		COST/SWU $		PRODUCTION M SWU's				LAST YEAR YEAR OF GDP
		1 *	2 *	1 *	2 *	GDP	GCEP	AVLIS	TOTAL	
15	Normal AVLIS only	15.3	10.2	51.69	34.46	0	0	296	296	1983
16	Normal Set V GCEP Only	14.3	10.3	32.51	22.63	0	455.2	0	455.2	1983
17	Maximum Accelerated AVLIS Only	22.2	17.1	40.73	31.38	0	0	545	545	1983
18	Set V GCEP with added 3 buildings only	18.3	13.8	31.75	23.95	0	576.3	0	576.3	1983

* Column 1 is burdened with sunk costs for CIP/CUP and for cancelled GCEP where appropriate. Column 2 deletes all sunk costs.

NOTE: ALL COSTS ARE FY 1984 DOLLARS

PRODUCTION SCENARIOS

	CASE 1				CASE 2				CASE 3				CASE 4			CASE 5		
	PRODUCTION	GDP	SET III	AVLIS	PRODUCTION	GDP	SET IV	AVLIS	PRODUCTION	GDP	SET V	AVLIS	PRODUCTION	GDP	SET V	PRODUCTION	GDP	AVLIS
1984	15	15	0	0	15	15	0	0	15	15	0	0	15	15	0	15	15	0
1985		14.6	0.4			14.6	0.4			14.6	0.4			14.6	0.4			
1986		14.3	0.7			14.3	0.7			14.3	0.7			14.3	0.7			
1987		13.9	1.1			13.9	1.1			13.9	1.1			13.9	1.1			
1988		13.4	1.6			13.3	1.7			13.1	1.9			13.1	1.9			
1989		12.8	2.2			12.6	2.4			12.1	2.9			12.1	2.9			
1990		11.7	3.3	0		11.3	3.7	0		9.0	6.0	0		9.0	6.0		15	0
1991		9.4	4.6	1		8.8	5.2	1	15	3.6	10.4	1	15	4.6	10.4		14	1
1992		5.2	5.8	4	15	3.4	7.6	4	19.2	0	15.2	4	15.2	0	15.2		11	4
1993	15	1.8	7.2	6	16.3	0	10.3	6	26.6		20.6	6	20.6		20.6		9	6
1994	17.8	0	8.8	9	22.2		13.2	9	35.4		26.4	9	26.4		26.4		6	9
1995	21.8			13	26.2			13	39.4			13					2	13
1996	22.8			14	27.2			14	40.4			14					1	14
1997	23.8			15	28.2			15	41.4			15				15	0	15
1998	24.8			16	29.2			16	42.4			16				16		16
1999	25.8			17	30.2			17	43.4			17				17		17
2000	26.8			18	31.2			18	44.4			18				18		18
2001	26.8			18	31.2			18	44.4			18				18		18
2002	26.8			18	31.2			18	44.4			18				18		18
2003	30.8			22	35.2			22	48.4			22				22		22
2004	31.8			23	36.2			23	49.4			23				23		23
2005	32.8			24	37.2			24	50.4			24				24		24
2006	33.8			25	38.2			25	51.4			25				25		25
2007	34.8			26	39.2			26	52.4			26				26		26
2008	35.8	0	8.8	27	40.2	0	13.2	27	53.4	0	26.4	27	26.4	0	26.4	27	0	27
TOTAL	567	112.1	158.9	296	634.3	107.2	231.1	296	846.8	95.6	455.2	296	551.8	96.6	455.2	444	148	296
PRODUCTION COST B$	21.4	10.3	4.6	6.5	20.8	9.9	4.4	6.5	19.4	8.8	4.1	6.5	13.0	8.9	4.1	20.1	13.6	6.5

PRODUCTION SCENARIOS

	CASE 6				CASE 7				CASE 8				CASE 9			CASE 10		
	PRODUCTION	GDP	SET III	AVLIS	PRODUCTION	GDP	SET IV	AVLIS	PRODUCTION	GDP	SET V	AVLIS	PRODUCTION	GDP	SET V	PRODUCTION	GDP	AVLIS
1984	10	10	0	0	10	10.0	0	0	10	10	0	0	10	10	0	10	10	0
1985		9.6	0.4			9.6	0.4			9.6	0.4			9.6	0.4			
1986		9.3	0.7			9.3	0.7			9.3	0.7			9.3	0.7			
1987		8.9	1.1			8.9	1.1			8.9	1.1			8.9	1.1			
1988		8.4	1.6			8.3	1.7			8.1	1.9			8.1	1.9			
1989		7.8	2.2			7.6	2.4			7.1	2.9			7.1	2.9			
1990		6.7	3.3	0		6.3	3.7	0	10	4.0	6.0	0	10	4.0	6.0		10	0
1991		4.4	4.6	1	10	3.8	5.2	1	11.4	0	10.4	1	10.4	0	10.4		9	1
1992	10	0.2	5.8	4	11.6	0	7.6	4	19.2		15.2	4	15.2		15.2		6	4
1993	13.2	0	7.2	6	16.3		10.3	6	26.6		20.6	6	20.6		20.6		4	6
1994	17.8		8.8	9	22.2		13.2	9	35.4		26.4	9	26.4		26.4	10	1	9
1995	21.8			13	26.2			13	39.4			13				13	0	13
1996	22.8			14	27.2			16	40.4			14				14		14
1997	23.8			15	28.2			15	41.4			15				15		15
1998	24.8			16	29.2			16	42.4			16				16		16
1999	25.8			17	30.2			17	43.4			17				17		17
2000	26.8			18	31.2			18	44.4			18				18		18
2001	26.8			18	31.2			18	44.4			18				18		18
2002	26.8			18	31.2			18	44.4			18				18		18
2003	30.8			22	35.2			22	48.4			22				22		22
2004	31.8			23	36.2			23	49.4			23				23		23
2005	32.8			24	37.2			24	50.4			24				24		24
2006	33.8			25	38.2			25	51.4			25				25		25
2007	34.8			26	39.2			26	52.4			26				26		26
2008	35.8	0	8.8	27	40.2	0	13.2	27	53.4	0	26.4	27	26.4	0	26.4	27	0	27
TOTAL	520.2	65.3	158.9	296	590.9	63.8	231.1	296	808.2	57.0	455.2	296	512.2	57	455.2	386	90	296
PRODUCTION COST B$	17.1	6.0	4.6	6.5	16.8	5.9	4.1	6.5	15.8	5.2	4.1	6.5	9.3	5.2	4.1	14.8	8.3	6.5

PRODUCTION SCENARIOS

	CASE 11				CASE 12			CASE 13			CASE 14		
	PRODUCTION	SET V	AVLIS	GDP	PRODUCTION	AVLIS	GDP	PRODUCTION	GDP	AVLIS	PRODUCTION	GDP	SET V
1984	10	0	0	10	10	0	10	10	10	0	10	10	0
1985		0.4		9.6			10					9.6	0.4
1986		0.7		9.3			10					9.3	0.7
1987		1.1		8.9			10					8.9	1.1
1988		1.9		8.1			10					8.1	1.9
1989		2.9		7.1			10					7.1	2.9
1990	10	6.0	0	4.0	10	0	10		10	0	10	4.0	6.0
1991	11.4	10.4	1	0	11.4	1	10.4		9	1	10.4	0	10.4
1992	17.2	13.2	4		17.2	4	13.2		6	4	15.2		15.2
1993	19.2		6		19.2	6	13.2		4	6	20.6		20.6
1994	22.2		9		22.2	9	13.2	10	1	9	26.4		26.4
1995	26.4		13.2		26.4	13	13.4	18	0	18	27.9		27.9
1996						18	8.4	22		22	30.5		30.5
1997						22	4.4	26		26	33.0		33.0
1998						26.4	0	30		30	36.3		36.3
1999								34		34			
2000								38		38			
2001								42		42			
2002								45		45			
2003													
2004													
2005													
2006													
2007													
2008	26.4	13.2	13.2	0	26.4	26.4	0	45	0	45	36.3	0	36.3
TOTAL	509.6	247.8	204.8	57.0	509.6	363.4	146.2	635	90	545	633.3	57	576.3
PRODUCTION COST B$	11.9	2.2B	4.5B	5.2B	21.5	8.0	13.5	$20.3B	$8.3B	$12.0B	$10.4B	$5.2B	$5.2B

PRODUCTION SCENARIOS

	CASE 15		CASE 16		CASE 17		CASE 18		CASE 19	
	PRODUCTION	AVLIS	PRODUCTION	SET V	PRODUCTION	AVLIS	PRODUCTION	SET V	PRODUCTION	GDP
1984	0	0	0	0	0	0	0	0	10	10
1985			0.4	0.4			0.4	0.4		
1986			0.7	0.7			0.7	0.7		
1987			1.1	1.1			1.1	1.1		
1988			1.9	1.9			1.9	1.9		
1989			2.9	2.9			2.9	2.9		
1990	0	0	6.0	6.0	0	0	6.0	6.0	10	10
1991	1	1	10.4	10.4	1	1	10.4	10.4	11.4	11.4
1992	4	4	15.2	15.2	4	4	15.2	15.2	17.2	17.2
1993	6	6	20.6	20.6	6	6	20.6	20.6	19.2	19.2
1994	9	9	26.4	26.4	9	9	26.4	26.4	22.2	22.2
1995	13	13			18	18	27.9	27.9	26.4	26.4
1996	14	14			22	22	30.5	30.5		
1997	15	15			26	26	33.0	33.0		
1998	16	16			30	30	36.3	36.3		
1999	17	17			34	34				
2000	18	18			38	38				
2001	18	18			42	42				
2002	18	18			45	45				
2003	22	22								
2004	23	23								
2005	24	24								
2006	25	25								
2007	26	26								
2008	27	27	26.4	26.4	45	45	36.3	36.3	26.4	26.4
TOTAL	296	296	455.2	455.2	545	545	576.3	576.3	509.6	509.6
PRODUCTION COST	6.5	6.5	4.1	4.1	12.0	12.0	5.2	5.2	46.9	46.9

Senator **Domenici**. Thank you very much, Mr. Grant; Mr. Broussard, vice president, Arizona Public Service Co., chairman, Gas-Cooled Reactor Associates Management Committee.

STATEMENT OF D. L. BROUSSARD, VICE PRESIDENT, ARIZONA PUBLIC SERVICE CO., AND CHAIRMAN, GAS-COOLED REACTOR ASSOCIATES MANAGEMENT COMMITTEE

Mr. **Broussard**. Thank you, Mr. Chairman. I am from Phoenix. I am here as chairman of the Gas-Cooled Reactor Associates Management Committee, which is an association formed by the electric utilities to assist the industry and the Government in the completion of some 25 percent of efforts to bring the gas-cooled reactor, the high temperature gas reactor, into commercial availability for the utilities, and later as we have now discovered as a heat source for heavy industry.

The HTGR is an advanced second generation nuclear power system that offers some distinct advantages. It addresses most if not all of the issues being raised by the public and the industry in general concerning nuclear power. It should be a highly acceptable, easy to site reactor in the future.

These advantages have been proven through its involvement at Peach Bottom in Pennsylvania, the initial prototype unit in Colorado with the project at Fort St. Vrain—in Public Service of Colorado—and through our continued work in engineering and design.

The program is now focused on a lead project which is the last step in the commercialization of the steam cycle concept of the HTGR, and we have identified lead project candidates around the country and the southeast of Florida and the southwest and Arizona and California and the northeast and on the gulf coast of Texas. These candidates are involved in our development at this time. They are sincere and have a strong business interest in seeing the commercialization of it.

The strategy calls for a framework made up of the utilities and industrial team that has been identified. Two of the prominent members are here at the table with me today—General Electric and GA Technologies—who have carried this program for many years.

The industry has spent approximately $1 billion to this date in private funds, and the Government has expended approximately half that amount—$500 million—to bring the technology to this stage. We will need the continued strong support of the Federal Government during the next few years as we bring the level of confidence of the engineering design, conceptual design, particularly the work with the licensing criteria which the NRC is now beginning to address in a stronger way, to give the industry, the industrial sector, the confidence it needs to take over the program and complete it with the private funds. We anticipate that as the lead project is built, it would require funds that would be divided approximately 25 percent with the Federal Government and 75 percent with private industry.

I think this is a strong indication that the private industry is willing and ready and capable to do the job on an immediate basis.

Gas-cooled reactors, spending approximately $2, between $2 and $3 million a year, have a budget of $3 million for 1983. Public Service of Colorado individually has spent $14 million in improving Fort St. Vrain, and has about $20 million budgeted for 1983—again, an indication of strong industry support for the program.

We have enjoyed strong support from this committee. We have budgeted $59 million for 1984 to keep the program on its schedule. We anticipate that in the interest of conservation of funds on a tight budget that a minimum of $40 million would be required to keep our resource base together.

I thank you, Mr. Chairman, for the opportunity to be here, and we appreciate this committee's continued support.

[The prepared statement of Mr. Broussard follows:]

STATEMENT SUBMITTED FOR THE RECORD
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
FY 1984 DOE AUTHORIZATION
HIGH-TEMPERATURE GAS-COOLED REACTOR PROGRAM
D. L. BROUSSARD
VICE PRESIDENT OF ARIZONA PUBLIC SERVICE COMPANY
AND CHAIRMAN OF
GAS-COOLED REACTOR ASSOCIATES MANAGEMENT COMMITTEE
MAY 3, 1983

Mr. Chairman and Members of the Subcommittee, my name is D. L. Broussard and I am Vice President of Arizona Public Service Company and Chairman of Gas-Cooled Reactor Associates (GCRA) Management Committee. I appreciate the opportunity to present Utility/User support for the High-Temperature Gas-Cooled Reactor (HTGR) Program. I would like to briefly outline our funding requirements in FY 1984 for the HTGR Program. We are requesting $59 million in FY 1984 DOE authorizations, which includes $2 million for R&D capital equipment and $3 million for spent fuel treatment activities. These funding levels are necessary in order to advance the HTGR Lead Project on a timely basis consistent in the Lead Project Strategy Plan, which has been submitted to Congress and the Department of Energy.

The Utility/User industry through GCRA, in conjunction with a broad sector of the nuclear industry and strong nonpartisan Congressional support has been striving to maintain a viable HTGR Program. The focus of this effort has been the development of a 2240 MW(t) Steam Cycle/Cogeneration (SC/C) Lead Project. In addition to its demonstrated application for highly efficient electricity generation, the HTGR-SC/C system is ideally suited to cogeneration applications with various industrial processes that are presently dependent on fossil energy resources. Both of these applications incorporate a single, standardized HTGR nuclear steam supply system. As an advanced, second generation nuclear power system, the HTGR offers important advantages with regard to inherent safety and low environmental impact. These features result in less reliance on engineered safety systems, added margins for meeting certain licensing criteria, greater siting flexibility, and reduced radiation exposure to plant personnel. Further, given the multibillion dollar investment of central power plants today, the HTGR's inherent safety provides important plant investment protection to both shareholders and rate payers.

As you are well aware, financial and regulatory difficulties and reduced growth in many parts of the country have resulted in the deferral or cancellation of numerous generation facilities during recent years. The industry's inability to build new capacity in the near-term implies a strong future demand for replacement and new power plants when the financial and regulatory environments are more receptive. In the interim, it is essential that the Nation maintain the foresight for continuing the development of promising energy alternatives such as the HTGR.

To date, the U.S. has invested about $1.5 billion on the HTGR. Of this total the private sector has spent approximately $1.0 billion. This support has been instrumental in the design and construction of two HTGR facilities: the Peach Bottom developmental plant which was operated by the Philadelphia Electric Company and the Fort St. Vrain demonstraton plant which is currently operating and providing electricity for the Public Service Company of Colorado (PSC).

With regard to the Fort St. Vrain plant, I am pleased to report that in November 1982 the NRC granted authorization for the plant to operate routinely at 100% power or 330 MW(e). As you know, the Fort St. Vrain power plant first went critical in January 1974 and has operated at near 70% power since January 1978. Operation was restricted to 70% capacity by the NRC until technical issues associated with core temperature fluctuations were resolved. With core restraining devices installed, a successful full power test run was authorized by the NRC and completed in November 1981. All plant systems and components performed at or near design conditions during the full-power test run. Based on these test results, PSC applied for and was granted NRC authorization to operate the plant at the 100% power level. PSC is currently operating the plant at 70% of capacity as the result of a conscious management decision based on several factors, including the fuel warranty agreements with GA Technologies. As of year-end 1982, the Fort St. Vrain plant has delivered over 3 billion kilowatt-hours of net electrical energy.

Fort St. Vrain has provided critical confirmation and demonstration of many key HTGR concepts. In particular, fuel integrity and radiation exposure to plant personnel have had an exceptional operating record. Operating data indicate that the amount of radioactivity carried in the helium coolant has been less than two percent of the design limit, demonstrating the structural integrity of the coated fuel particles and the graphite core structure. A comparison of personnel exposure data for Fort St. Vrain and light water reactor plants in the U.S. indicates that Fort St. Vrain has had an average annual person-rem exposure rate per GW(e)-year of less than two percent of the average exposure rate in light water reactor plants. This low personnel exposure level is even more significant in view of the fact that Fort St. Vrain has virtually unlimited access into the reactor building for all operations and maintenance personnel. Other major contributions of Fort St. Vrain have been in the areas of core physics confirmation, plant control and response, and plant performance at high temperatures. Plant operating experience to date has demonstrated predictable, easily managed performance even during extreme modes of operation including temporary loss of forced cooling. The high core heat capacity has shown temperature transients to be slow, predictable, and easily controlled. Operation to date has achieved 1400°F primary loop helium temperatures, 1000°F steam temperatures, and a net efficiency of 38.5%--the highest of any nuclear plant in the U.S. We are confident that Fort St. Vrain will continue to provide valuable kilowatt-hours for the customers of PSC as well as critical information regarding the demonstration of many HTGR concepts.

During the past year, significant progress has been achieved in advancing the HTGR-SC Lead Project that will be the final step in commercializing the steam cycle based HTGR technology. Last July, eight senior GCRA utility executives representing five HTGR Project candidates, sent a letter to OMB Director Stockman and past DOE Secretary Edwards confirming their interest to move ahead with an HTGR Lead Project initiative. These five regional project candidates are summarized as follows:

1. In the Intermountain Region, Idaho Power Company, Public Service Company of Colorado and Colorado-Ute Electric Association would utilize the HTGR-SC/C system to meet new generation requirements. Evaluation studies have focused on the potential of such a Project located at or near the Idaho National Engineering Laboratory (INEL). Such a Project would centralize the generation capacity for sharing throughout the Intermountain Region and utilize the associated resources at INEL. In addition, the INEL site has the growth potential for a nuclear energy park with associated fuel cycle facilities and cogeneration applications. Alternatively, an Intermountain Project could be located at the Fort St. Vrain site that would accommodate a second HTGR with the attendant benefits of direct experience transfer from the Fort St. Vrain demonstration plant.

2. In the Gulf Coast Region, Gulf Oil Refining and Marketing Company has evidenced interest in the HTGR-SC/C system as a source of cogenerated steam for its Port Arthur refinery, assuming other industrial users in the area indicate similar desires. In addition, the HTGR plant would provide electricity to the Gulf States Utilities' grid. Ongoing Project evaluation studies have indicated the feasibility of the refinery's transition from gas and oil to a central station cogeneration facility, identified potential sites proximate to the refinery, and are addressing the key institutional issues of ownership and financial arrangements.

3. In the Southeast Region, Florida Power and Light has an interest in the HTGR-SC/C system for future generation capacity at their South Dade site. This site is located in the environmentally sensitive area of Southeast Florida near large load centers experiencing rapid growth. A siting evaluation has been conducted to quantify and confirm the siting advantages of the HTGR at this site. Bob Uhrig is here today to address the Florida Power and Light interest in the HTGR.

4. In the Mid-Atlantic Region, Public Service Electric and Gas and Philadelphia Electric Company have an interest in the future electric generation and cogeneration applications of the HTGR-SC/C system. In the cogeneration application, the HTGR-SC/C system would supply process steam to industrial customers seeking to expand and/or shift from in-house gas and oil reliance or to potentially new synthetic fuel industries. Project evaluation studies have identified the cogeneration potential of the HTGR-SC/C system to such applications.

5. In the Southwest Region, Arizona Public Service (APS) has an interest in the HTGR-SC/C to meet future electric generation requirements. APS has three large nuclear reactors under construction at the present time with the last one scheduled for operation in 1986. The site at Palo Verde, west of Phoenix, is adequate to receive two additional units and is ideally suited for the HTGR. The critical water situation, siting requirements and expected need for power in the 1995-2000 time period add importance to APS's interest in the HTGR.

These identified Utilities/Users have an interest in and need for an HTGR system that would be deployed in the middle to late 1990's; hence, warranting progressive commitments during the next few years. In order to provide a framework for analyzing the financial and organizational structure required for a viable Project, GCRA in cooperation with the other Program participants has prepared a Lead Project Strategy Plan which outlines a proposed approach for completing the Project, including proposed cost and risk sharing arrangements between the public and private sectors. The July letter to Stockman and Edwards forwarded a copy of the Lead Project Strategy Plan. Both the letter and the Plan are available upon request.

The Strategy Plan poses a phased commitment to the Lead Project whereby all parties progressively develop their role and financial commitment based on solid technical and economic information, as well as institutional arrangements developed during each Project phase. The intent of this strategy is that a private sector entity will support the Lead Plant costs and risks to the extent of its commercial value. In addition, the Utility/User industry, through GCRA and EPRI, will support a share of front-end costs associated with the Lead Project. Vendor/supplier support for the Lead Project will come from an industrial team that will provide the design and manufacturing capabilities required for the Project. The vendor/supplier team would share in the Lead Project risks through firm prices on the nuclear steam supply system, including associated components and fuel supply, and provide a broad vendor/supplier infrastructure for subsequent HTGR plants. GA Technologies is committed to playing a key leadership role in establishing this vendor/supplier team. Government financial support is required for the first-of-a-kind design and technology development for systems, components, and fuel cycle. Additionally, it would provide Project financing support to offset first-of-a-kind costs and risks associated with the Lead Plant. The intent is to finance the Lead Project through a cooperative private/public sector effort with the private sector paying the major fraction, approximately 75%, of the total Lead Project costs.

In addition to the Utility/User support for a Lead Project, there has been significant progress with all elements of the HTGR Program. Utility/User financial support through GCRA and EPRI continue to grow. The utility industry spent approximately $2 million in 1982 and has budgeted about $3 million for the Program in 1983. The bulk of these resources support a full-time staff that provides Project development and integration services to the HTGR Program. In addition, the Public Service Company of Colorado has spent approximately $14 million in 1982 and has budgeted about $20 million in 1983 for Fort St. Vrain improvements that support the continued invaluable demonstration role of this plant. The vendor/supplier support has broadened and strengthened, as reflected by the increasing involvement of General Electric and Combustion Engineering along with GA Technologies for the Lead Plant's design and development activities. Even though the HTGR Program has been excluded from the Administration's budget proposals, the DOE has been supportive of the Lead Project initiative and has increasingly focused the available budget resources toward the critical path technical requirements of the Lead Project. In addition, NRC activities are responsive to the Lead Project's licensing criteria development requirements, as reflected in their HTGR Safety Research Program Plan.

With respect to government support for FY 1984, GCRA urges the Senate Subcommittee on Energy Research and Development to provide the DOE budget authority necessary to continue to advance the HTGR-SC/C design and technical programs and support the industry's Lead Project development activities. Your continued support in FY 1984 is crucial in our efforts to stabilize the roles of industry and government which are necessary to establish the HTGR option. To accomplish this the following tasks are scheduled during the balance of FY 1983 and in FY 1984: (a) refine and advance the Lead Project Strategy Plan, with special emphasis on establishing acceptable financial and ownership arrangements to all parties; (b) continue development of multiple Lead Project candidates through site specific application studies; (c) complete and implement the Lead Project Management and Licensing Plans; and (d) advance the Lead Plant design through the existing baseline structure, including completion of the conceptual design, the initiation of the preliminary design and licensing, and the continuation of the fuel and component testing activities. It is also important to continue work on promising advanced HTGR systems. In particular, the Program should continue to advance the modular HTGR system by completing the concept evaluation of the modular system and to establish design and technology development requirements. For all these activities, every effort should be made to continue international cooperation with Germany and expand cooperation with Japan and others to minimize costs and risks of HTGR development. A minimum DOE budget level of $37 million, which includes $2 million for R&D equipment, is required to adequately support the technology development activities in FY 1984. In addition, support should continue for the HTGR thorium fuel cycle development. Work in this area should emphasize spent fuel management and continuing the cooperative technical programs with the Federal Republic of Germany. These activities will require $3 million in FY 1984.

Mr. Chairman, we recognize that these budget recommendations must be considered in the context of a constrained budgetary and economic environment and in the absence of an Administration budget request to fund the HTGR Program. However, we feel that industry support for the Program and the need to maintain the HTGR option is stronger than ever. We have carefully evaluated our budget recommendations and have limited the requested funding to be consistent with the Administration's intent to freeze FY 1984 budget outlays to FY 1983 levels. If we were to proceed with the Lead Project in the most cost-effective manner, a DOE budget of $59 million would be required in FY 1984, which includes $2 million for capital equipment and $3 million for spent fuel treatment activities . This funding level would clearly signal Congressional support for the Lead Project initiative and provide the basis for greater private sector support in 1983 and 1984. We respectfully request that the Subcommittee on Energy Research and Development consider this proposed funding level in the course of the FY 1984 budget process.

Mr. Chairman, we appreciate the opportunity to present the Utility/User viewpoint to your Subcommittee. With your continued support, we will continue to make real progress toward the realization of the HTGR technology.

Senator **Domenici**. Thank you, Mr. Broussard. I also want to personally thank you and your association, your company, for the fine support you gave to us in our uranium where we attempted to recognize the major disaster that is occurring in the country with the uranium industry disappearing very, very rapidly from the scene, and you did help us, and I want you to know that we appreciate it.

Mr. **Broussard**. Thank you.

Senator **Domenici**. Dr. Harold Agnew, president of GA Technologies—it's nice to see you again. I'm sorry it is under such abbreviated circumstances, but that's the best I can do today.

Dr. **Agnew**. I understand that.

Senator **Domenici**. You have a propensity for summarizing and talking quickly, and we will ask you to do that.

Dr. **Agnew**. All right.

STATEMENT OF DR. HAROLD M. AGNEW, PRESIDENT, GA TECHNOLOGIES, INC.

Dr. **Agnew**. Mr. Chairman, Mr. Melcher, I am Harold Agnew, president of GA Technologies, and I appreciate your permitting me to present the views of my colleagues in support of the continuation of development of high temperature gas-cooled reactor, the HTGR, and continued support for the magnetic fusion program.

Mr. Chairman, I would ask your permission to submit for the record along with my formal statement a copy of a document entitled, "HTGR Program, March 1983," which will supplement the information provided in that particular statement and further define the technical and operational features of the HTGR.

Senator **Domenici**. It will be made a part of the record.

Dr. **Agnew**. Mr. Chairman, I don't know if you noticed yesterday's lead article in The Wall Street Journal, but there was a particular sentence that caught my eye, the first paragraph, and I quote,

> Somehow it is little surprise to us that in retrospect the main lessons of the Three Mile Island accident were that the public safety was not really endangered but that there was an often unregulated insurance risk in an industry in which you can lose one billion in a half an hour.

When the Congress in its wisdom enacted Public Law 96-567, the Nuclear Safety Research, Development and Demonstration Act of 1980, they elected to suggest to the Department of Energy that in addition to improving training, in addition to improving mechanical equipment, that the Department should search for a new technology which would enhance the safety and efficiency of nuclear power in this country. Now the HTRG is an advanced reactor system which offers a unique capability to serve not only in the role of electrical generation in a more efficient manner, but also to serve a second role, that is of providing high temperature steam and heat to meet the needs of the process industries. It is the only nuclear reactor which can really substitute for fossil fuels across the board.

This technology offers for the ultimate user benefits which would support its commercial development. These include a substantial increase in thermal efficiency, the highest safety margins of any commercial nuclear power system, reduced levels of radiation exposure for operating personnel, and I think in the future this is going to be an overriding consideration; lower levels of waste discharge, reduced cooling water requirements which will be vital for the southwest, and increased siting flexibility which, of course, is related to the reduced cooling requirement.

These benefits are not only of interest to the ultimate user but we believe can also impact on the future acceptance of the public of the nuclear technology.

Mr. Broussard mentioned the private sector has the only nuclear program in the Nation which has received the majority of the support from the private sector. That program continues to enjoy the support of a large section of our utility industry as represented by the Gas-Cooled Reactor Associates. As Mr. Broussard mentioned, there is a commitment on the part of industry for the demonstration plants. The private sector will provide 75 percent which is essentially the basis for the cost of the facility, with the Government providing an additional 25 percent through continued DOE development and experimentation.

As he mentioned, the 1984 budget requirement set forth in the program plans submitted to the Department of Energy for continuation of the lead project was $56 million, including $2 million for capital equipment and $3 million for the spent fuel treatment program. This level of activity is fully consistent with the most effective use of program resources and the initial operation of a lead plant by 1997.

However, in recognition of the constraints placed on the Federal budget, we in conjunction with other of the program participants have also developed a support level which would provide for maintenance of critical capability and progress on the key critical path activity. That minimum budget would provide a total of $40 million for the HTGR program—approximately the same level of funding appropriated by the Congress in fiscal years 1981, 1982, and 1983, and that would include $2 million for capital equipment.

I would now like to switch and talk about magnetic fusion which I know is very dear to your heart.

Reinforced national commitment to magnetic fusion is warranted by its vast promise. Earlier someone talked about renewable resources, and I would say fusion is more renewable than any other resource. I feel the tokamak program in particular is poised for a major step forward. With the addition of three model initiatives that I wish to describe to you, the fiscal 1984 Presidential budget keeps the program on track with providing the Nation with this vital energy option on an acceptable time scale.

The past year has been an especially productive one for the magnetic fusion effort. The preeminent scientific development has been the demonstration of record values of plasma beta with data on doublet III which is a large program of tokamak at GA. The values obtained are necessary to produce desirable power densities of tokamak reactors. Thus the achievement has been received with great enthusiasm among the fusion researchers throughout the whole world.

Engineering and technological progress has kept pace with the advances on the scientific front. The most important engineering milestone was the impressive on-time startup of the tokamak fusion test reactor at Princeton. This accomplishment is evidence of how far the program has progressed toward readiness to tackle a reactor scale project. However, the absence of major new initiatives jeopardizes this progress over the longer term. While commitment to a first generation reactor is not possible in the present budgetary climate, the program should take the steps necessary to prepare for this eventuality. I would like to recommend two cost-effective steps that require modest increments to the fiscal 1984 Presidential budget.

These are, first, development of a conceptual design of a tokamak fusion core demonstration device, a proposal endorsed by the Magnetic Fusion Advisory Team, which requires an additional $6 million in fiscal 1984.

Second, establishment of a national ion cyclotron heating engineering program to produce plasma heating hardware needed on doublet III, which would require an additional $10 million in 1984—when these two initiatives are in place, it would provide the program elements to support a future commitment to a reactor tokamak.

The strengthening of the tokamak program is also important for the United States retaining a leading position in the world effort to harness fusion power.

Mr. Chairman, again I would like to thank you and your colleagues for your continued support of the high temperature gas-cooled reactor and our Nation's magnetic fusion program.

Thank you very much.

[The prepared statement of Dr. Agnew follows:]

STATEMENT SUBMITTED FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

U.S. SENATE

FY'84 DEPARTMENT OF ENERGY AUTHORIZATION

HIGH TEMPERATURE GAS-COOLED REACTOR PROGRAM
MAGNETIC FUSION PROGRAM

HAROLD M. AGNEW

PRESIDENT

GA TECHNOLOGIES INC.

MAY 3, 1983

Budget Action Recommended FY'84

Department of Energy

High Temperature Gas Cooled Reactor (includes $2M for capital equipment)	$ 40M
HTGR Spent Fuel Treatment Program	$ 3M
Magnetic Fusion Program (President's request of $467M plus $6M for Tokamak Fusion Core Demonstration and $10M Ion Cyclotron Heating Engineering Program)	$483M

Mr. Chairman and Members of the Subcommittee, I am Harold M. Agnew, President of GA Technologies Inc. I appreciate your permitting me to present the views of my company in support of a continuation of development of the High Temperature Gas-Cooled Reactor (HTGR) and continued support for the magnetic fusion program. The HTGR is well known to you and many of your Members and staff. However, allow me to quickly define its major features for those new Members who may be reviewing the FY'84 Department of Energy budget without the benefit of previous program briefings.

The historic role of nuclear power has been in electrical generation. The HTGR offers a unique capability to not only serve this role in a more efficient manner but also to serve a second role, that of providing high temperature steam and heat to meet the future needs of the process industries for low cost, clean energy. We see the long range contribution to be made by nuclear in this energy sector to be as signifiçent as its contribution in electric generation. The HTGR is the only nuclear reactor which has this potential.

As would be anticipated with an advanced, second generation reactor the technical features of the HTGR have been selected to offer benefits to the user which support its commercial development and deployment. These benefits include a substantial increase in thermal efficiency; the highest safety margins of any commercial nuclear system; reduced levels of radiation exposures for operating personnel; lower levels of gaseous, liquid and solid waste discharge; reduced cooling water requirements; and increased siting flexibility. These benefits are not only of interest to the ultimate user but we believe can also impact upon the future acceptance of nuclear systems by the public.

The basic characteristics of the HTGR have been demonstrated by the operation of the 40 MW (e) Peach Bottom I nuclear plant during the years 1967 through 1974, and the 330 MW (e) Fort St. Vrain nuclear station, which successfully reached 100% of design power in 1981 and is continuing to verify key design features which would be incorporated in commercial scale HTGRs. The current stage of development provides the basis for the next step in the evolution of a commercial system, the construction and operation of an HTGR Lead Plant, the prime objective of which is to demonstrate a full scale commercial technology. Gas-Cooled Reactor Associates, the utility/user organization supporting the HTGR, testifying here today, will review the current Lead Plant Project activities.

Mr. Chairman, I would ask your permission to submit for the record, along with my formal statement, a copy of a document entitled "HTGR Program, March 1983" which will supplement the information provided in this statement and further define the technical and operational features of the HTGR.

As you are aware, since the initial HTGR project at Peach Bottom, which was undertaken in conjunction with 52 electric utilities, this program has continued to enjoy the support of a large segment of our nation's electric utility industry. This support is exemplified by Gas-Cooled Reactor Associates, which is represented here today by its Chairman, Richard Walker, who is also President of Public Service Company of Colorado. The support of the utilities results from the advanced features of the HTGR, all of which combine to provide the promise of a competitive system with enhanced environmental benefits, substantially reduced consequences to the public, the work force, and the reactor facility itself while in standard operation or during any potential accident. Through FY'83, the utilities along with GA Technologies have invested well over $1 billion to develop this technology -- our Nation's only nuclear program which has received the majority of its development funding from the private sector.

Although the base of utility support is for base load electricity production, the utilities view the application of the HTGR to industrial processes as a major opportunity to improve the future energy balance and energy economics in the United States and as an area for potential broadening of the utility role thru jointly sponsored cogeneration projects. The HTGR has the unique capability to serve a large segment of the industrial energy needs providing process steam at temperatures initially up to 1000°F. Cogeneration application studies have shown that HTGR steam electric/cogeneration systems integrate easily with major processes including those in the chemical, petroleum, shale oil, tar sands, and metal refinery industries, and that the economics are favorable when compared with the other alternatives. In the future as advanced higher temperature versions of the HTGR become available, even broader applications will become practical. The HTGR is the only nuclear technology with these unique capabilities.

Private sector participation has been a key element of the HTGR program. However, the proposed government role in support of development of appropriate technology and first-of-a-kind design remains a key incentive to encourage such private sector participation. The program plan submitted to the DOE is based on the private sector accepting responsibility for 75% of the lead plant program costs representing the commercial value of the plant and related costs, with the government providing the additional 25% through continued DOE research and development funds. For its part, GA Technologies was the pioneer in the development of HTGR technology, is currently recognized as the world leader in this field and continues to believe strongly in the concept and the contribution that it can make to meeting the world's need for clean, safe, low-cost energy. In addition to continuing investments in the technology GA has been moving forward in parallel with the DOE program and utility activities to ensure having in place a strong and experienced industrial team with the capability to undertake the design, manufacture of the HTGR nuclear system for a Lead Project and for commercial follow-on projects. Thus, the private sector utility/industry investment remains paramount in the commercial development of the HTGR.

International cooperation has long been a part of the High Temperature Gas-Cooled Reactor program in the United States. A formal agreement exists between the U.S. and the governments of Germany and Switzerland providing for a cooperative exchange program for the development of the HTGR. The benefits from such exchanges are enhanced by numerous exchange agreements existing between industrial participants in the U.S. and European programs. With Japan a number of industry level exchange agreements are in place and the Japanese have indicated their desire to develop closer relationships with the U.S. program on a government to government level. Those of us in the industrial sectors in the two countries are urging ways to formalize such expanded cooperation. The common technology requirements and many common objectives of the major German, Japanese, and the U.S. programs, provide a unique opportunity for instituting effective, cost beneficial joint development activities for the HTGR. We understand that the Soviet Union is also pursuing this technology.

The Congress of the United States, in a bipartisan effort, has long supported continued development of the HTGR and we at GA hav been greatly appreciative of this critical support. Although the HTGR has without exception been recommended for continued Department of Energy funding year after year in budget submissions to the Office of Management and Budget, that office has in recent years refused to support the DOE budget request. Consequently in the FY'84 DOE budget submittal to the Congress, the HTGR is absent. As you know, the utility industry has suffered from both financial and regulatory difficulties which has impacted their current ability and need to build new capacity. We are confident, however, that when these difficulties have diminished, and when the HTGR has progressed to the point where it can be considered for commercial deployment, it will be the system of choice by reason of advanced performance, investment protection and the improved prospect for public acceptance. A continuation of federal support of appropriate HTGR program activities is a critical element in maintaining utility, international, and public enthusiasm and technical progress so that this nuclear system will be available as a viable option when the nuclear role in meeting the Nation's energy demands is again recognized and vigorously pursued.

Key program goals, which I defined to you in my testimony of last year have, we are proud to say, been met with the FY'82 funds appropriated and signed into law in October of 1981. Multiple lead project candidates have been identified, in cooperation with GCRA and the DOE, a lead project strategy plan has been established, the conceptual design of the HTGR steam cycle/cogeneration reactor reached 60% completion, and the vendor/supplier team including GA, Combustion Engineering for heat exchanger support, and General Electric Company for circulator support continues. Technology development, critical to any future HTGR program, achieved major accomplishments. Construction of the developmental coater for LEU fuel particles was completed, prototypical processing units for fuel kernel manufacturing progressed, testing was performed of core models and incorporated design changes to verify the elimination of core fluctuations, preparation was made for the test facility for main circulator bearings and seals tests, air flow testsof upper and lower core plenums were initiated, and core seismic tests and correlations with structural dynamic analysis was completed. Advanced systems activities including design studies of small modular HTGR concepts also progressed.

Activities relating to the preapplication review and safety research work at the NRC continued in FY'82 with funds appropriated and authorized by the Congress.

The FY'83 program is well on the way toward completing the lead plant conceptual design, schedule and cost estimates, completing the management plan and licensing plan, completing the transfer of steam generator technology to Combustion Engineering, completing analysis of cogeneration plant configurations, and completing licensing criteria review and documentation preparation for submittal to NRC.

The FY'84 HTGR program plan has recently been submitted by the program participants to the DOE and with Congressional funding support, we intend to initiate the preliminary design and standard plant licensing activities, establish the basis for project ownership/financial arrangements, implement the lead project management plan, establish the reference site and initiate early site review with the NRC, complete full-scale core support performance tests in the high temperature helium test loop, initiate a full-scale partial section performance test on the core auxillary cooling system heat exchanger under normal and accident conditions, complete full-scale main circulator bearing and seal tests, and correlate USA and German experimental data in fission product transport characteristics. In the area of advanced systems we intend to initiate conceptual design and development for selected advanced HTGR systems. The spent fuel treatment program will complete spent fuel treatment studies specific to the lead plant and continue the required development program.

The FY'84 budget requirements set forth in the program plan submitted to the DOE for continuation of HTGR Lead project and advanced system activities is $56 million (including $2 million for capital equipment) and $3 million for the spent fuel treatment program. This level of activity is fully consistent with the most effective use of program resources and the initial operation of a Lead Plant by 1997. In recognition of the constraints placed on the Federal budget we, in conjunction with other of the program participants, have also developed a support level which although not meeting all goals would provide for maintenance of critical capabilities and progress on the key critical path activities. That minimum budget would provide a total of $43 million for the HTGR Lead Project, advanced systems and spent fuel treatment program activities (including $2 million for capital equipment). This is approximately the same spending level the Congress appropriated in FY's 1981, 1982 and 1983.

I would now like to turn to the Magnetic Fusion Program.

The past year has been an especially productive one for the GA fusion effort and for Doublet III in particular. The preeminent development was the demonstration on Doublet III of record values of plasma beta. The peak value obtained -- 4.5% -- represents a factor of two improvement over predecessor experiments and augurs well for the ability to produce desirable power densities in tokamak reactors. Because the question of achievable power density has long been the principal critical issue for the tokamak program, this demonstration has been received with great enthusiasm among fusion researchers.

Scientific successes at GA have been supplemented by advances made at other laboratories. Indeed the richness of the tokamak program has been a major factor in its impressive rate of progress. I urge the Committee to retain this vital feature of the program and to continue to support vigorous toroidal confinement research at MIT, ORNL, PPPL, and GA.

Engineering and technological progress has kept pace with advances on the scientific front. A prime example is the successful implementation of a state-of-the-art 60 GHz electron cyclotron heating system on Doublet III. We have also succeeded in injecting more than 5 MW of neutral beam power into a Doublet III plasma. Program-wide, the most important engineering milestone was the impressive on-time start-up of the Tokamak Fusion Test Reactor at Princeton. This accomplishment is evidence of how far the program has progressed toward readiness to tackle a reactor scale project.

These recent advances, taken together with other funded program elements which are still in the construction stage, are sufficient to propel the magnetic fusion program forward in the near term. In the mid-80s, the two principal vehicles in the tokamak program for demonstrating major progress toward reactor conditions will be TFTR and DIII-D (or Big Dee).

The absence of major new initiatives jeopardizes progress of fusion over the long term. While commitment to a first generation reactor is not possible in the present budgetary climate, the program should take the steps necessary to prepare for this eventuality in order to minimize slippage of the time scale for the ultimate commercialization objective. I recommend two cost effective steps that require modest increments to the FY 1984 Presidential budget. These are:

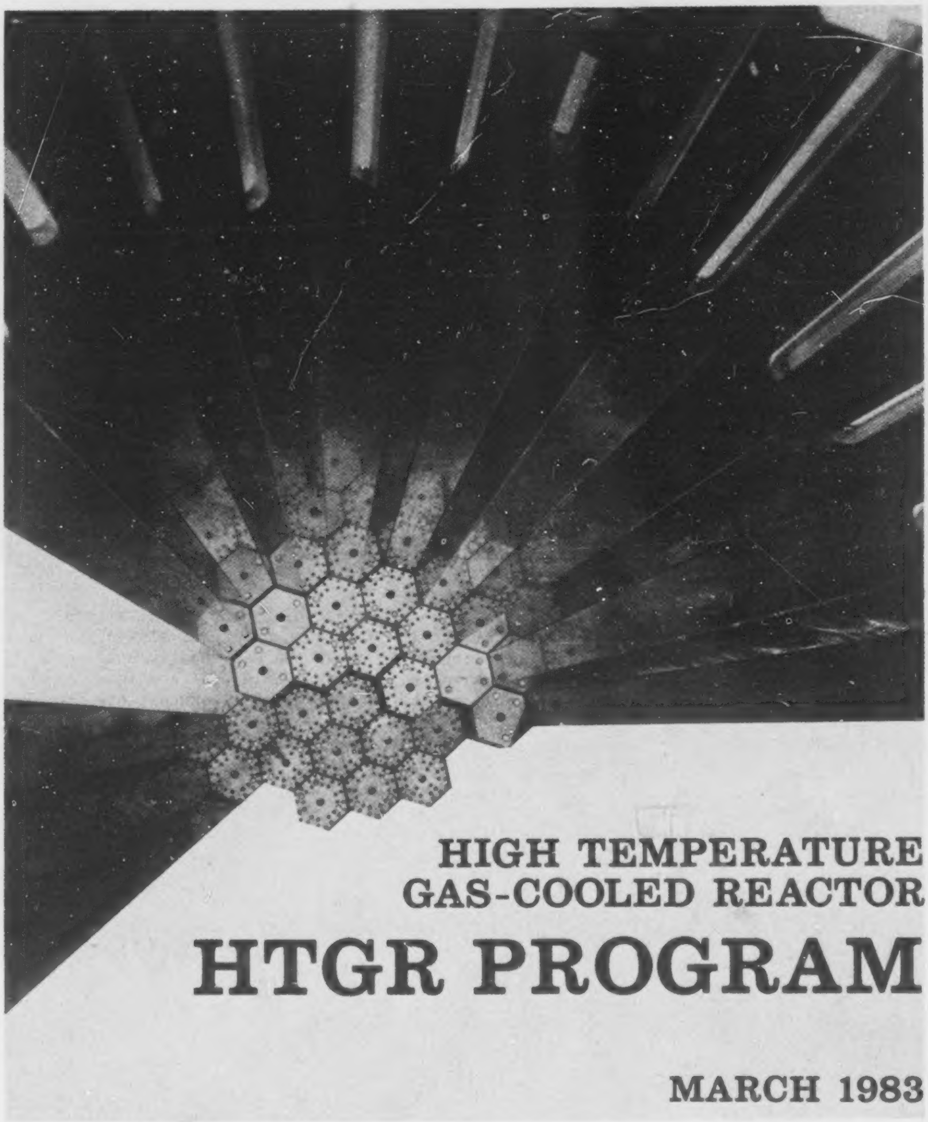
1) The commitment to develop a conceptual design of a Tokamak Fusion Core Demonstration device, an ignited tokamak that could become operational in the early 1990s. This activity requires an additional $6 million in FY 1984.

2) The establishment of a National Ion Cyclotron Heating Engineering Program to manage the engineering of ion cyclotron heating hardware, regarded as the most promising method for heating tokamak plasmas. The systems developed would be used to push TFTR and Big Dee to their performance limits on a time scale commensurate with providing near term guidance to reactor design. Later, the identical hardware could be used on a reactor. In FY 1984, this program will require an additional $10 million in BA and $5 million in BO.

When these two initiatives are undertaken, the tokamak community will have the program elements in place to support commitment to a reactor tokamak. One further investigation is also warranted in the near term: an evaluation of the options available for gaining experience with longer pulse operation. This strengthening of the tokamak program is important for the U.S. in retaining supremacy in the worldwide effort to harness fusion power.

On the international front our experience on Doublet III, which is now 3½ years into a 5 year cooperative program with the Japan Atomic Energy Research Institute, has been very favorable. The Japanese have gained valuable experience on the operation of an advanced tokamak facility while our program has benefitted greatly from major hardware additions funded by Japan.

The incorporation of the Big Dee into the program, which your Committee has wisely supported, makes us confident that we will provide a progressively increasing role in determining the form tokamak reactors will take. We are equally confident that, with your support, the magnetic fusion program as a whole will continue its steady progress toward providing the nation with an attractive, inexhaustible energy option.



HIGH TEMPERATURE GAS-COOLED REACTOR

HTGR PROGRAM

MARCH 1983

BRIEFING
DOCUMENT ON

HIGH TEMPERATURE GAS-COOLED REACTOR

HTGR PROGRAM

PREPARED BY
GA TECHNOLOGIES INC.

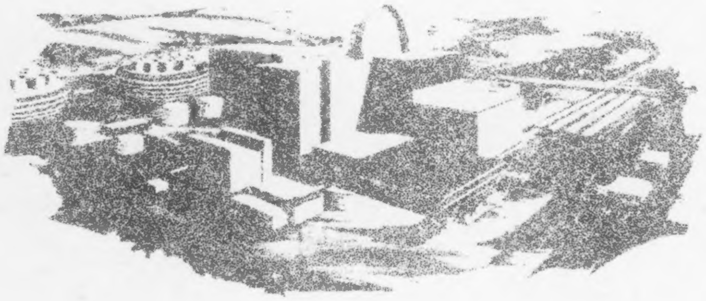
MARCH 1983

Preface

This document has been prepared by GA Technologies to provide background material on the High Temperature Gas-Cooled Reactor (HTGR) program useful to deliberations on the FY-84 nuclear budget. The HTGR program has maintained strong user support during a period of nuclear power uncertainty because the HTGR can uniquely fulfill a major role in the national energy picture, both as a second generation, safer approach to nuclear electric generation, and to supplement or displace fossil fuels in providing high temperature energy to the process industries.

During the past two years the DOE/industry program has continued to make significant progress in establishing the foundation for proceeding with an HTGR cogeneration lead plant project and in establishing the technological compatibility, environmental, and economic benefits for a number of specific cogeneration applications. Also during this period, the HTGR has been established as a leading candidate to meet the defense program need for a new production reactor.

The program participants (including the utility, process, and supplier industries) strongly urge the Congress to continue government support for the HTGR program in order to insure the availability of this unique option at such time as the institutional barriers to nuclear energy have been overcome.



HTGR Benefits

Multipurpose Energy Roles

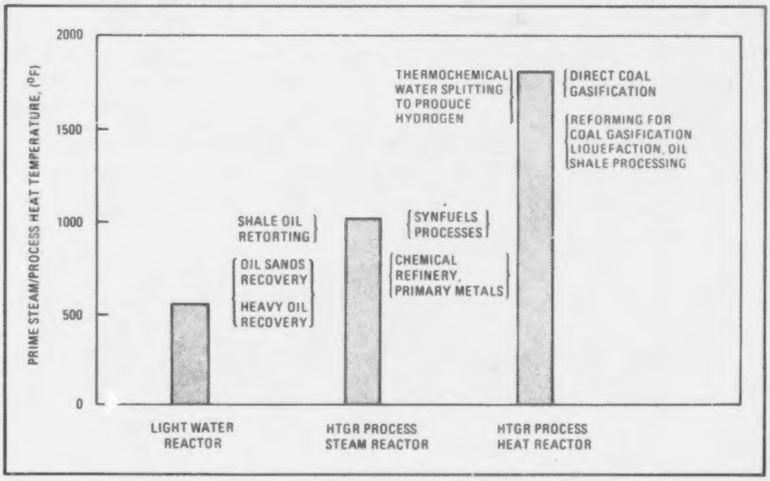
Unique capability for providing high temperature process steam or heat in cogeneration applications

- HTGR can produce 1000°F steam to meet industry needs while cogenerating electric power
- Can displace fossil fuels usage, reduce environmental impact of fossil combustion
- Future higher temperature HTGR process heat systems open additional industrial and synfuel applications for the use of clean, non-polluting nuclear process heat

Higher electricity production performance

- Higher thermal efficiency (up to 40%)
- Requires less uranium

Can contribute to all major energy demand sectors of the economy



Other Benefits

Higher levels of safety, operational and environmental compatibility

- Inherent safety results in maximum protection of public and investment, a basis for improved public acceptance
- Reduced exposures of operating personnel
- Lowest levels of gaseous, liquid and solid waste discharge
- Reduced cooling water requirements
- Improved siting flexibility

Program compatible with potential role of HTGR as a new production reactor

- Essentially all nuclear steam system hardware identical

Program can benefit from major international HTGR activities focused in Germany and Japan and recent strong interest of Japanese government in cooperative HTGR development program

Strong Industry Support

Concept has continuing support of a major segment of the nuclear utility industry, as well as major process industries

Lead plant program directed toward development of primary funding support from the private sector, direct government involvement limited to traditional front-end R & D funding

Industrial participants in program provide their individual strengths through specialized design and component design

HTGR Steam Cycle System

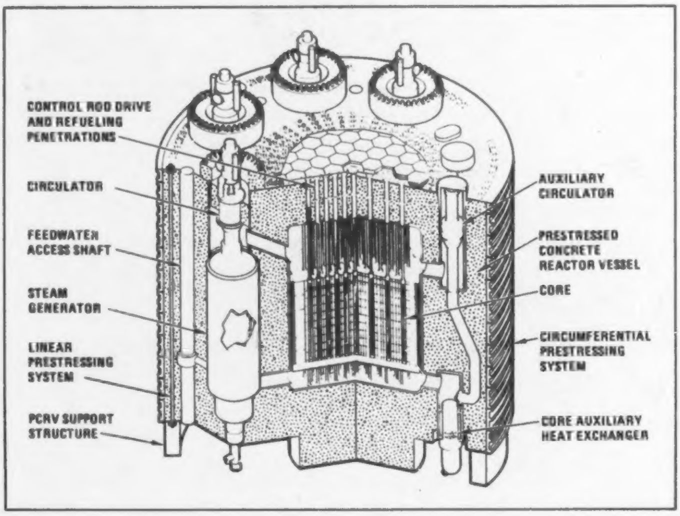
HTGR Reactor

In HTGR systems, helium gas is used as the coolant to remove the heat from the core. In the HTGR-steam electric/cogeneration system the helium is heated to about 1260°F. This heat is transferred in a steam generator to produce steam for process use and/or electricity production. The entire primary system including steam generators, helium circulators, and auxiliary heat exchangers, is housed within the thick-walled prestressed concrete reactor vessel. The fuel is contained in hexagonal graphite blocks, several thousand of which are stacked to make up the reactor core. Because of the systems high temperature capability, superheated steam can be produced, contributing to the thermal efficiency of about 40%, which is highest of any nuclear plant.

Standard Loop Design Allows Multiple Unit Rating

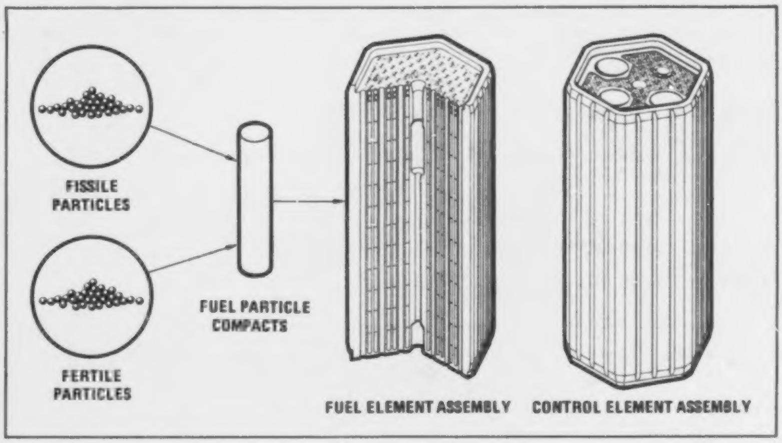
Using varying numbers of loops, HTGR system designs are available in ratings to match broad user needs

- 2 loop – 1170 MW (t) – 440 MW (e)
- 4 loop – 2240 MW (t) – 860 MW (e)
- 6 loop – 3360 MW (t) – 1300 MW (e)


CONTROL ROD DRIVE AND REFUELING PENETRATIONS
CIRCULATOR
FEEDWATER ACCESS SHAFT
STEAM GENERATOR
LINEAR PRESTRESSING SYSTEM
PCRV SUPPORT STRUCTURE
AUXILIARY CIRCULATOR
PRESTRESSED CONCRETE REACTOR VESSEL
CORE
CIRCUMFERENTIAL PRESTRESSING SYSTEM
CORE AUXILIARY HEAT EXCHANGER

HTGR Fuel

HTGR fuel is made up of tiny microspheres of uranium and/or thorium, oxides or carbides, each of which is coated with pyrocarbon and silicon carbide to retain fission products. These particles are mixed with a binder and formed into small compacts, (about 1/2 in. dia. × 2-1/4 in. long). The compacts are sealed into fuel cavities running vertically through 31 in. high hexagonal graphite fuel elements. The active core consists of stacks of these graphite fuel elements through which the helium coolant flows in vertical channels.


FISSILE PARTICLES
FERTILE PARTICLES
FUEL PARTICLE COMPACTS
FUEL ELEMENT ASSEMBLY
CONTROL ELEMENT ASSEMBLY

Fuel cycle cost advantage under comparable conditions

- Costs competitive in stow-away mode
- Cost benefits increase with increasing yellowcake (U_3O_8) costs and with recycle

Extends U_3O_8 resource base

- Uses 25% to 50% less uranium than LWR depending on fuel cycle mode

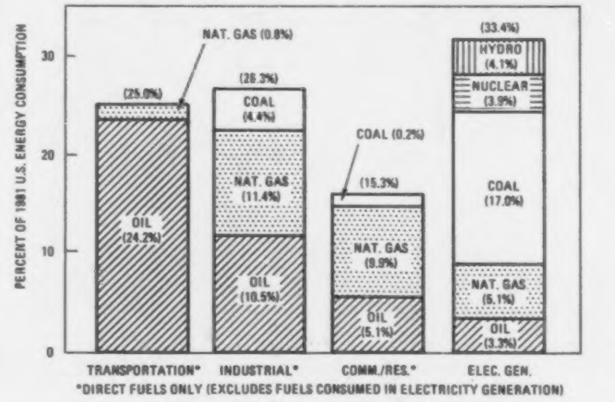
Flexible uranium/thorium fuel cycle

- Can use either low or high enriched uranium cycle

Cogeneration Market

About 20 quads (26%) of the total U.S. gross energy consumption in 1981 was in the industrial sector, with the primary fuels being oil and natural gas. If electricity generated to meet industrial needs is also included, the total industrial energy consumption in 1981 was about 26 quads (35%). To avoid increases in production costs due to escalating oil and gas prices and to meet projected changes and growth in new and existing industrial processes, industry will be forced to turn to coal and nuclear fuels as alternate energy sources.

U.S. GROSS ENERGY CONSUMPTION IN 1981 – 74.4 QUADS



*DIRECT FUELS ONLY (EXCLUDES FUELS CONSUMED IN ELECTRICITY GENERATION)

Industrial energy requirements

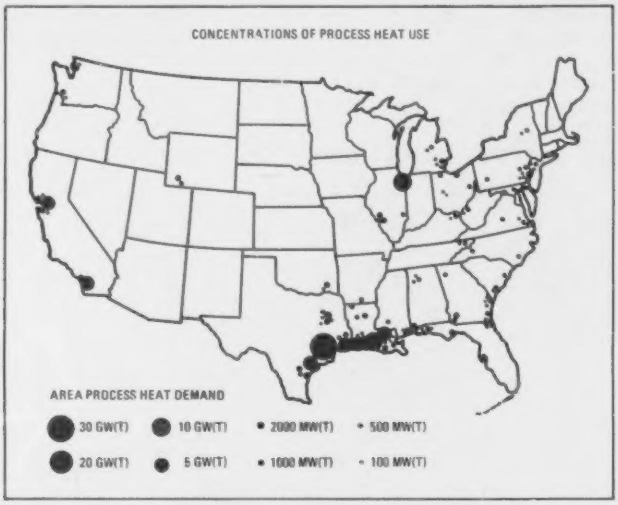
- About 15 quads (77%) of the requirements are at temperatures of 1000°F or less
- About 9 quads (44%) of the requirements are in the form of steam

Process industries require both steam and electricity

An HTGR variable cogeneration plant can accommodate most industrial applications

Markets For Process Steam Are Concentrated

Recent studies identified current locations at which combined industrial steam requirements offer potential for the use of centralized HTGR plants to supply nuclear process steam and cogenerated electric power.


CONCENTRATIONS OF PROCESS HEAT USE
AREA PROCESS HEAT DEMAND
30 GW(T)
10 GW(T)
2000 MW(T)
500 MW(T)
20 GW(T)
5 GW(T)
1000 MW(T)
100 MW(T)

A single 1170 MW (t) HTGR cogeneration system can provide up to 2,500,000 lb/hr of process steam and from 115 to 410 MW of electricity

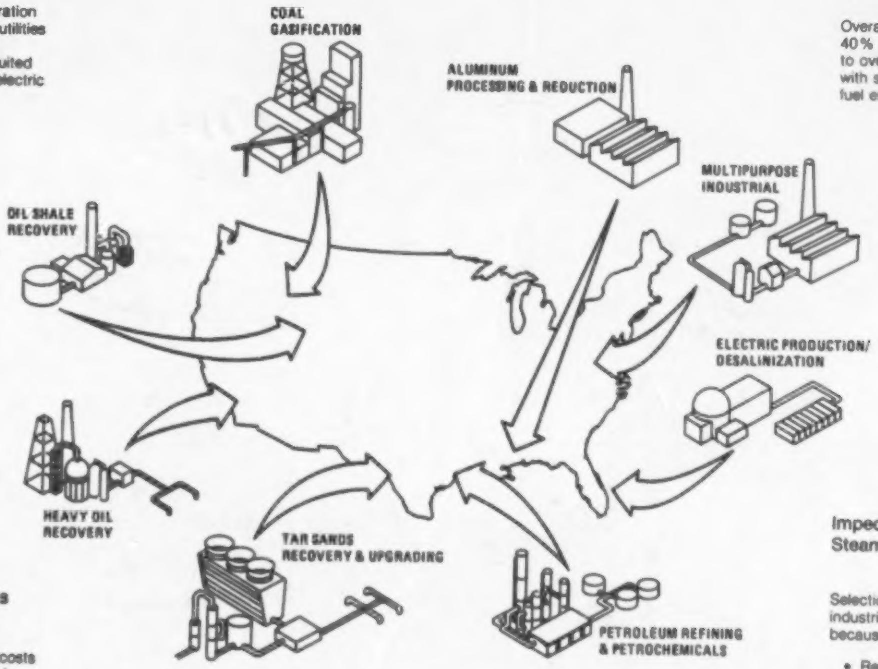
Future HTGR Cogeneration Market Potential Large

During the 2000-2020 time period, the total potential process steam market has been estimated at over 100 equivalent HTGR units of the 1170 MW (t) size. These units would be deployed to provide cogenerated steam and electric power for industrial applications. Another potential market exists for higher temperature HTGR process heat systems to meet additional high temperature needs such as the production of synthetic fuels and hydrogen.

HTGR Cogeneration Applications

Technically Compatible

Application studies done in cooperation with major process industries and utilities show that the reference HTGR cogeneration plant design is well suited to meet most process steam and electric power requirements


COAL GASIFICATION
ALUMINUM PROCESSING & REDUCTION
OIL SHALE RECOVERY
MULTIPURPOSE INDUSTRIAL
ELECTRIC PRODUCTION/ DESALINIZATION
HEAVY OIL RECOVERY
TAR SANDS RECOVERY & UPGRADING
PETROLEUM REFINING & PETROCHEMICALS

Reduced Energy Costs And Lowered Environmental Effects

For all typical applications, HTGR cogeneration systems show energy costs to be reduced by 15% to 40%, and emissions such as SO_x, NO_x, CO_2, and particulates to be lowered by 40% to 100%, when compared with coal fired alternatives

Increased Energy Utilization

Overall energy utilization increased from 40% for electric power generation only to over 90% with nuclear cogeneration, with significant conservation of fluid fossil fuel energy resources

Impediments to Nuclear Process Steam Are Institutional

Selection of nuclear process steam by industries currently difficult principally because of institutional problems

- Regulatory uncertainties
- Schedule uncertainties
- Unfavorable nuclear climate
- Higher initial cost than alternatives

HTGR Safety and Environmental Features

Higher safety level of HTGR results from inherent physical and nuclear properties

- Massive graphite core provides slow temperature response, does not require fast acting shutdown system
- Graphite core and ceramic fuel stable to extreme temperatures
- Non-reactive helium coolant
- Massive, redundant, prestressed concrete reactor vessel
- Inherent shutdown mechanisms (large negative temperature coefficient)

Inherent features are supplemented with engineered safety systems

- Independent auxiliary cooling system
- Independent emergency reactivity shutdown system
- Reactor containment building

Ample time to respond to loss of core cooling

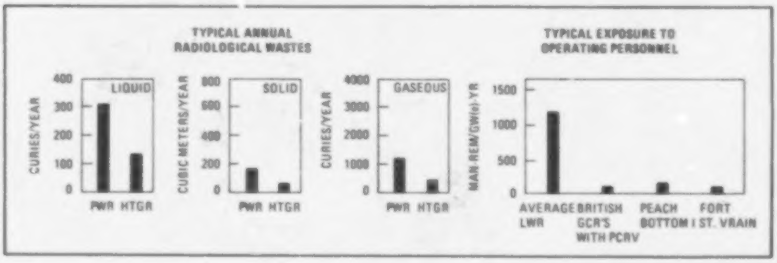
- Hours instead of minutes before damage to core

Reduced radioactivity wastes

- Helium cooled HTGR plants inherently release into the plant process streams less radioactivity than an LWR

Significantly reduced operator exposure

- Experience at Peach Bottom I, Fort St. Vrain and Gas-Cooled Reactors in the U.K. indicate that radiation exposures to operating and maintenance personnel will be about 1/10 of those for an LWR



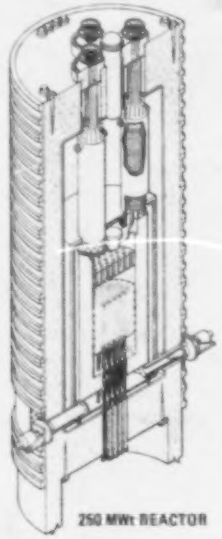
HTGR Advanced Systems

The HTGR steam cycle will provide a technical base for advanced systems with higher operating temperatures. Two such systems are the process heat and small modular reactor.

HTGR-Process Heat

The process heat HTGR provides helium core outlet temperatures of 1472° to 1652°F. An intermediate heat exchanger transfers the heat to a secondary helium loop incorporating a reformer that can be used to react steam and methane to form hydrogen and carbon monoxide, a reducing gas that can be integrated into such processes as oil shale retorting, coal liquefaction, and coal gasification, to produce transportation liquids, ammonia or synthetic pipeline gas. At higher core outlet temperatures (1652° to 1832°F) the reforming reaction can be performed more efficiently and a direct steam-coal reaction can be utilized to produce high-Btu gas or hydrogen via thermochemical water-splitting.

Small Modular HTGR


250 MWt REACTOR

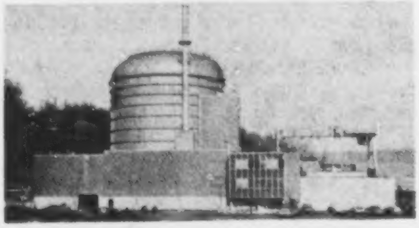
Small [250 MW (t)] modular HTGR systems (both steam cycle and reforming versions) are under assessment. The steam-cycle/cogeneration system consists of a reactor core and primary loops housed in either a steel or prestressed concrete reactor vessel. The primary coolant loop contains steam generators and horizontally mounted helium circulators. This equipment is arranged to promote natural circulation shutdown cooling of the core. In the reformer version of the small modular HTGR, an integral steam generator/reformer replaces the steam generator in the upper section of the reactor vessel.

Technology Background

United States Program

Substantial experience, technology, and test and manufacturing facilities currently exist in U.S.

Peach Bottom Unit 1



40 MW (e) Peach Bottom Unit 1 HTGR was operated successfully by Philadelphia Electric Company from 1967 to 1974, when plant was shut down for decommissioning after completing planned demonstration program.

Test Facilities

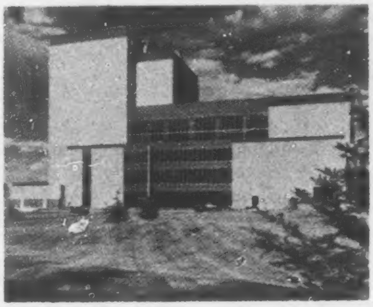
HTGR test facility compound, including air flow test facility, component test tower, PCRV models, tendon test facility, PCRV wire-winding machine, and helium circulator test facility

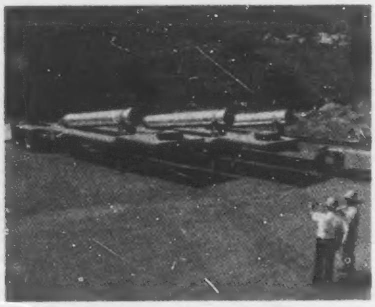
Manufacturing Facilities

Facilities available for manufacture of HTGR fuel

Fort St. Vrain

- Obtained 100% power license on October 5, 1982
- Has operated at full power with over 38.5% thermal efficiency
- All plant systems and components have performed at design conditions
- Has generated over 3 billion kW hrs of net electrical energy to date
- Fuel performance excellent, activity in helium coolant less than 2% of design limit
- Average annual personnel exposure rate significantly less than in LWR plants, despite virtually unlimited personnel access into reactor building and absence of secondary containment
- Two segments of discharged fuel shipped to HTGR dry storage facility at Idaho Chemical Processing Plant with no problems. First operational AFR storage in U.S.





Program Funding Through 1982

Funds expended on the HTGR program through 1982, including the construction of the Peach Bottom No. 1 and Fort St. Vrain plants, amount to $1.53 billion dollars. Of this total, $555 million (or 36%) has been supplied by the government and $975 million (or 74%) has come from industry.

International Program

Experience

Substantial international experience on gas-cooled reactor technology supports U.S. program

Germany

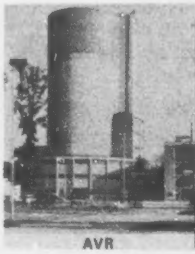
- AVR – 15 MW(e) HTGR with pebble bed fuel has generated 1.2 million MW/hr since startup in 1967
- THTR-300 MW(e) HTGR with pebble bed fuel – PCRV pressure test carried out in September 1982, rise to power scheduled in late 1984
- Broadly based HTGR program with long term goal of nuclear coal gasification, strongly supported by coal/utility industries
- Funding in 1983: $250 million for THTR-300 and $75 million for R & D

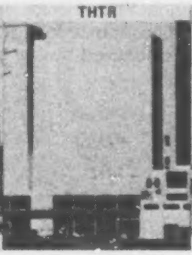
United Kingdom

- Over 555 reactor years of operating experience with gas-cooled reactors
- DRAGON – first HTGR, operated from 1964-1975
- AGRs – 8,800 MW(e) program of seven 2-unit stations going well, both in construction and operation
- Hartlepool, Heysham 1 and Dungeness B AGR stations going on line during 1983
- Heysham 2 and Torness AGR stations in construction for operation in 1987-1988

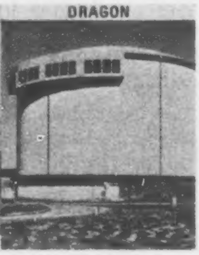
France

- Over 100 reactor years of operating experience
- Carmen II facility – core-flow and hot duct tests conducted – capability for steam generator boiling stability tests


AVR

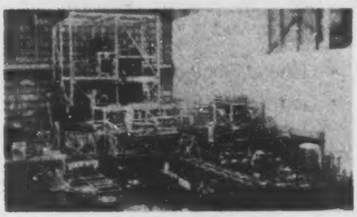

THTR

HARTLEPOOL


DRAGON

Japan

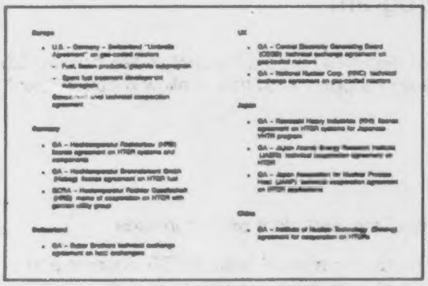
- Multi-purpose very high temperature gas-cooled reactor (VHTR) under development since 1969
- Operation of 50 MW (t) experimental VHTR in 1990 confirmed as goal in government's nuclear energy development program
- Hendel 10 MW helium test loop facility began operation in 1982 at 1000°C temperatures
- Interested in HTGR cooperation with U.S.
- Cogeneration HTGR evaluation initiated by nuclear supplier group in 1982 in cooperation with U.S. industry



HENDEL

Technical Exchange Agreements

Relevant HTGR experience is brought into the U.S. program through government and industry exchange agreements



HTGR Funding Through 1982

	Million $
Federal Republic of Germany	$1,700
Japan	300
France, United Kingdom, Switzerland	250
Total	$2,250

HTGR Program Description

The current government/industry HTGR program, which is focused on the development and demonstration of a commercial-scale HTGR steam cycle cogeneration system, has broad industry, user, and national laboratory involvement

GA Technologies, the world leader in HTGR technology, is the lead industrial firm involved in the program. However, other experienced industrial companies are also directly involved in key areas

- General Electric Company
- Combustion Engineering Company
- Bechtel Group Inc.
- United Engineers & Constructors

HTGR program activities are also conducted at National Laboratories

- Oak Ridge National Laboratory
- Los Alamos National Laboratory
- Brookhaven National Laboratory
- Idaho National Engineering Laboratory

Gas-Cooled Reactor Associates (GCRA), represents the utility/user interests in support of the program, and performs an overall program integration activity for the government

Lead Plant Program

The major fraction of the HTGR program activities are directed toward technology development and design support activities to allow a commitment to an HTGR lead plant project

Objectives

The major objectives of the lead plant project include

- Demonstration of full commercial scale HTGR systems and components including features incorporating technology evolution and Fort St. Vrain operational experience
- Establishing the licensing criteria for follow-on commercial HTGR systems
- Confirming incentives of the HTGR nuclear system for electric production and cogeneration
- Establishing a broad industrial infrastructure to support a subsequent commercial HTGR industry

Schedule

The lead plant program schedule is dependent upon the level of funding available but is directed toward completion of project definition activities and a conceptual design in 1983 with commercial operation in the 1996 to 1997 period.

Lead Plant Funding Approach

A key project definition phase task is to develop management, funding, and risk sharing arrangements

- Industry to bear the major portion (commercial value) of the lead project costs
- Direct government participation limited to front-end support of design and development
- HTGR lead plant project costs are estimated to total about $2.14 billion (in 1983 dollars), with $506 million (or 24%) coming from the government and $1,635 million (or 76%) being furnished by industry.

Other Program Activities

In addition to primary efforts on base technology development and the steam electric/cogeneration lead plant project design and applications, the HTGR program also includes other secondary and complimentary activities

- Conceptual design of higher-temperature versions of the HTGR (e.g., reforming process heat HTGR)
- Feasibility assessment of small [approx. 250 MW (t)], modular HTGR systems for electric/cogeneration and process heat applications
- Investigation of waste treatment and spent fuel storage for near-term closure of the HTGR fuel cycle, plus continued development of technology for eventual reprocessing of HTGR-type uranium/thorium fuel elements
- Development of safety/licensing criteria specific to the HTGR, and review of long-range research plans for verification of HTGR safety
- International cooperation

Utility and Industry Support

Electric Utility Support Thru GCRA

- In 1978 a utility organization, Gas-Cooled Reactor Associates (GCRA), was formed to provide support and guidance to program. GCRA utilities currently represent over 30% of installed electric generating capacity in United States, over 25% of on-line nuclear capacity and about 40% of nuclear capacity now under construction.

American Public Power Association
Arizona Public Service
Colorado-Ute Electric Association
Delmarva Power & Light
Empire State Elec. Energy Research Corp.
    Central Hudson Gas & Electric
    Consolidated Edison
    Long Island Lighting
    New York State Electric & Gas
    Niagara Mohawk Power
    Orange & Rockland Utilities
    Rochester Gas & Electric
Florida Power & Light
Gulf States Utilities
Idaho Power
National Rural Electric Cooperative Association
Northeast Utilities
    Connecticut Light & Power
    Hartford Electric Light
    Western Massachusetts Electric
    Holyoke Water Power
Pacific Gas & Electric
Pacific Power & Light
Philadelphia Electric
Public Service of Colorado
Public Service of New Mexico
Public Service Electric & Gas
Puget Sound Power & Light
Salt River Project
San Diego Gas & Electric
Tennessee Valley Authority

Industrial User Support

- In 1979 a group of major industrial firms formed a process heat users group to support continued development of HTGR. Most of these companies merged into a process heat advisory committee established by GCRA in 1981

Allied Chemical
Consolidated Natural Gas Service
Gulf Oil
Inland Steel
Kaiser Aluminum & Chemical
Mobil Research & Development
Owens-Corning Fiberglass
Scallop Coal
United Gas Pipe Line

In August 1982 GCRA sponsored its fourth annual HTGR utility/user conference, which was attended by over 200 representatives of industry, government, and utilities from 75 organizations and six countries.

FY-82 HTGR Program Accomplishments

HTGR Steam Cycle/Cogeneration Lead Project

- Identified multiple lead project candidates through site-specific/application studies
- Established lead project strategy plan as framework for lead project deployment
- Established initial baseline for design and technology development activities through broad review by program participants
- Completed 60% of conceptual design
- Advanced vendor/supplier team through GA subcontract arrangements with CE for heat exchanger support and GE for circulator support

Technology Development

- Completed construction of developmental coater for LEU fuel particles
- Completed prototypical processing units for fuel kernel manufacturing
- Performed testing of core models and incorporated design changes to eliminate fluctuations
- Prepared test facility for main circulator bearings and seals tests
- Initiated air flow tests of upper and lower core plenums
- Completed core seismic tests and correlations with structural dynamic analysis

Advanced Systems

- Initiate design studies of small modular HTGR concepts
- Initiated development of new wrought alloys for high temperature applications

Spent Fuel Treatment Program

- Performed several test runs in cold pilot plant
- Completed tests on head end treatment of German pebble bed fuel

NRC Safety/Licensing Activities

- Completed topical reports on HTGR safety for NRC review
- Initiated source term study for HTGR

FY-82 NATIONAL PROGRAM FUNDING

FOR HTGR APPLICATIONS AND BASE TECHNOLOGY	*$35 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 3 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITIES	*$ 4 MILLION*

FY-83 HTGR Program

HTGR Steam Electric/Cogeneration Lead Project

- Advance lead project candidates and lead project strategy plan through site-specific and application studies
- Complete conceptual design, schedule, and cost estimates with associated documentation
- Complete management plan and licensing plan for lead plant project
- Complete transfer of steam generator technology to Combustion Engineering
- Complete analysis of cogeneration plant configurations
- Complete licensing criteria review and prepare documentation for submittal to NRC

Technology Development

- Perform hot cell destructive examination of FSV test fuel element
- Demonstrate pilot-scale LEU fissile kernel process through final heat treating
- Perform tests on improved fuel element design to verify elimination of core temperature fluctuations
- Complete 1/6 scale air flow model test of the core lower plenum, steam generator inlet sections and auxiliary heat exchanger inlet sections
- Complete a seismic test on full-scale section of steam generator helical bundle

Advanced Systems

- Complete preconceptual design of small modular reactors for cogeneration and process heat applications
- Establish advanced systems design and technology development requirements

Spent Fuel Treatment Program

- Complete fluid-bed burner off-gas treatment test program
- Complete lead plant spent fuel transportation/storage/processing studies

NRC Safety/Licensing Activities

- Interact with NRC on source term study and safety research program

FY-83 NATIONAL PROGRAM FUNDING:

FOR HTGR PROJECT AND BASE TECHNOLOGY	*$36 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 3 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITIES	*$ 4 MILLION*

Recommended FY-84 HTGR Program

HTGR Steam Electric/Cogeneration Lead Project

- Initiate preliminary design and licensing phase
- Establish project ownership/financial arrangements
- Implement lead project management plan
- Establish reference site (s) and initiate early site review with NRC
- Complete full-scale core support performance test in high temperature helium test loop
- Initiate full-scale prototype hot duct test in high temperature helium test loop
- Initiate full-scale partial section performance test on the core auxiliary cooling system heat exchanger under normal and accident conditions
- Complete full-scale main circulator bearing and seal test
- Correlate USA and German experimental data in fission product transport characteristics

Advanced Systems

- Initiate conceptual design and development for selected advanced HTGR system with emphasis on international cooperation

Spent Fuel Treatment Program

- Complete spent fuel treatment study for lead plant and continue required development program

NRC Safety/Licensing Activities

- Initiate standard plant issue review
- Continue safety research and licensing criteria development

RECOMMENDED FY-84 NATIONAL PROGRAM FUNDING:

FOR HTGR LEAD PROJECT AND ADVANCED SYSTEMS	*$37 TO 56 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 3 TO 5 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITIES	*$ 3 MILLION*

(LOWER VALUE REPRESENTS THE CRITICAL CAPABILITIES LEVEL)

Senator **Melcher** [presiding]. Thank you very much. The next witness is Dr. Richards, general manager, Advanced Reactor Systems Department of the General Electric Co.

STATEMENT OF DR. ROBERT B. RICHARDS, GENERAL MANAGER, ADVANCED REACTOR SYSTEMS DEPARTMENT, NUCLEAR FUELS AND SPECIAL PROJECTS DIVISION, GENERAL ELECTRIC CO.

Dr. **Richards**. Thank you, Mr. Chairman. My name is Robert B. Richards. I am general manager of the Advanced Reactor Systems Department of the General Electric Co. Our department is responsible for the management of all reactor and fuel cycle developments that have commercial nuclear power as their eventual application with the exception of the light water reactor applications.

The testimony I will be submitting for the record has got three main parts, and I will summarize each of these very briefly.

First I might mention that the General Electric Co. does have a strong interest in the high temperature gas reactor development. We have been working in this field for the past 7 or 8 years, and we are particularly interested in the potential that this reactor has for application of these high temperatures to the process heat industry.

Now in my testimony I have a few remarks on what I call the HTGR lead plant. This is the plant that is being developed, design is being developed by GCRA. General Electric is highly supportive of this lead project. We are involved in some of the systems engineering and the plant dynamics and control aspects of this project, and we propose to continue to support this project and we hope to enlarge our participation in it in the years ahead.

Now the second part of the testimony deals with what we call the advanced modular HTGR. This is work on a small unit, small HTRG, on the order of 200 to 300 megawatts thermal. These units are of such a size that they might be fabricated in a factory or controlled in the factory and perhaps shipped in a nearly complete state by rail or by barge. Several such units could make up a process heat plant and this should make it possible to have reduced construction schedule as compared to the construction schedule of a large conventional plant.

We feel that the modularization of process heat could have special applications. It might provide higher availability to the user by creating a mineature energy source grid or network. It may make the HTGR acceptable to markets that might not otherwise be possible with a larger plant. We believe this modular technology can provide an attractive basis for expanding international cooperation, particularly with countries such as West Germany and Japan who have active HTRG programs for process heat development underway at the present time. Countries could become involved with us in these modular programs and both parties could save money in the developmental cost.

The final part of the testimony contains a few remarks about the merits of process heat. We pointed out previously that the substitution of a nuclear heat source for fossil fuels—coal, oil, and so forth—can provide positive benefits in the areas of the conservation of resources and of the cleanliness of our environment. While coal reserves are very large, it seems to us that they can be put to cleaner, more efficient uses than those obtained simply through direct burning methods. While we now appear to have an oil glut, this probably won't last forever, and transportation will always have first call on oil reserves.

The eventual conversion of coal to liquid fuel can greatly extend our capability to satisfy this demand which now uses about one-fourth of the energy consumed in the United States.

Concerning our surrounding environment, as we expand the application of nuclear heat sources for the cogeneration of electricity and process heat, we believe we are moving in the direction of reducing those very annoying problems of acid rain and the greenhouse effect, both of which have been attributed at least in part to the burning of fossil fuels. We all know that the solution to these distressing problems will not come overnight. It would appear prudent, however, to develop technology base that could eventually offer real solutions to the undesirable side effects of continuing to burn fossil fuels as we do today.

We believe that the HTGR when developed to its full potential can play a major role in providing these solutions.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Richards follows:]

TESTIMONY OF

ROBERT B. RICHARDS
GENERAL MANAGER, ADVANCED REACTOR SYSTEMS DEPARTMENT
NUCLEAR FUELS & SPECIAL PROJECTS DIVISION
GENERAL ELECTRIC COMPANY

ON

DOE FY 1984 BUDGET REQUEST
FOR THE
HIGH TEMPERATURE GAS COOLED REACTOR PROJECT

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

MAY 3, 1983

HTGR TESTIMONY

My name is Robert B. Richards. I am General Manager of the Advanced Reactor Systems Department of the General Electric Company. Our Department is responsible for the management of all Reactor and Fuel Cycle Developments that have commercial nuclear power as their eventual application with the exception of the light water reactor applications.

The General Electric Company has a strong interest in the HTGR program. Principally, it has been focused on the potential of the HTGR to generate very high gas temperatures that may be utilized by the process industries - chemical, petroleum, etc. No other reactor system at the present time possesses such a potential to serve the process heat market.

HTGR LEAD PLANT

General Electric is contributing to the design of the steam cycle/cogeneration lead plant. Our contributions are primarily in the areas of systems engineering and plant dynamics and control. The program being proposed by GCRA is one that calls for DOE support during the R&D and preliminary design phases, with the work being carried out with such thoroughness that industry, users and investors can assess the risks of conducting a future project under private sponsorship. We in GE believe this to be a proper approach to HTGR development and compatible with the intentions of the Administration and the DOE to encourage greater involvement of the private sector. We also welcome GCRA's strong efforts to encourage interest and participation by potential process heat industrial users. We hope to continue to enlarge our participation in the lead plant project.

ADVANCED MODULAR HTGR

The present GCRA/DOE development program also includes work to develop a modular gas cooled reactor - eventually capable of generating higher gas temperatures than possible in the present lead project. GE has been assigned the technical lead for this phase of the program.

The modular units are of small capacity - 200 300 MWt. It is quite possible that these units could be fabricated and quality controlled in a factory and shipped in a nearly complete state via rail car or barge. Several such units could make up a process heat plant and should have a reduced construction schedule as compared to that of conventional large reactors.

The modularization of process heat energy sources could provide a higher availability to the user by creating a miniature energy source grid, or network, as a feature of the plant. The successful development of this modular concept could expand the accessible

HTGR process heat markets to those where high temperatures and high availability are particularly important.

The potential result of these innovative features when applied to the fabrication, construction and operation of the nuclear process heat plant is that capital risk can be significantly reduced to the investor/user.

The smaller size of the modular reactor also lends itself to lower R&D and testing costs since the testing of a full-size module may be possible at an affordable cost. Concern with scale-up to larger capacity plants can also be eliminated - capacity increases can be made simply be adding modules.

We believe that this modular technology can provide an attractive basis for expanding international cooperation, particularly with the countries of West Germany and Japan who have active HTGR programs for process heat development, while at the same time reducing the development costs incurred by each country. We strongly urge that the advanced HTGR work continue to receive your support.

MERITS OF NUCLEAR PROCESS HEAT

We have pointed out previously that the substitution of a nuclear heat source for fossil fuels (coal, oil, etc.) can provide positive benefits in the areas of the conservation of resources and of the cleanliness of our environment.

While coal reserves are very large, it seems to us that they can be put to cleaner, more efficient uses than those obtained simply through direct burning methods. While we now appear to have an oil glut, this probably won't last forever and transportation will have first call on oil reserves.

Eventual conversion of coal to liquid fuels can greatly extend our capability to satisfy this demand which now uses about one-fourth of the energy consumed in the United States.

Concerning our surrounding environment, as we expand the application of nuclear heat sources for the cogeneration of electricity and process heat, we believe we are moving in the direction of reducing those very annoying problems of acid rain and the greenhouse effect both of which have been attributed at least in part to the burning of fossil fuels.

We all know that the solution to these distressing problems will not come overnight. It would appear prudent, however, to develop a technology base that could eventually offer real solutions to the undesirable side effects of continuing to use fossil fuels as we do today. We believe that the HTGR, when developed to its full potential, can plan a major role providing these solutions.

Senator **Melcher**. Thank you, Doctor. The last witness on this panel will be Dr. Shohet, chairman of the University Fusion Association, professor of Electrical and Computer Engineering, the University of Wisconsin.

STATEMENT OF DR. J. LEON SHOHET, CHAIRMAN, UNIVERSITY FUSION ASSOCIATION, AND CHAIRMAN, PLASMA COORDINATING COMMITTEE, UNIVERSITY OF WISCONSIN

Dr. **Shohet**. Thank you, Mr. Chairman. I am Leon Shohet. I am, as you said, professor of Electrical and Computer Engineering at the University of Wisconsin. I am also director of the university's Torsatron/Stellarator Laboratory, and chairman of its Plasma Coordinating Committee.

I am also speaking to you today as chairman of the University Fusion Association established in 1979 of which I am the chairman. It is an organization of faculty and researchers whose members belong to 50 universities in the United States, all working in the area of fusion.

We appreciate your efforts on behalf of the fusion community of the Nation's universities, and we know that the task of authorizing the DOE budget is a very difficult one. Nevertheless, we believe it is important that you gain some perspective on the university role in the fusion program. From this, I think you will see just what we perceive to be the problems and opportunities for universities in fusion.

I must point out to you that this testimony represents a summary of the opinions of many members of the University Fusion Association Executive Committee. I was impressed by the fact that the general tone of all the comments has been very similar, that is, it will be very difficult for universities to continue their commitment to the fusion program because of the lack of adequate vehicles and financial resources. It is our hope that you will assist us in contributing toward the goal we all seek—commercial fusion power.

We would like you to consider the following points regarding the role of universities in fusion. One, universities should be considered a national resource for research, industry a national resource for product development.

Two, the present fusion budget provides only slightly more than 4 percent of its total to universities and has not kept pace with the scope and needs of the fusion program. This is an unconscionable loss of the great resources available in universities today.

Three, universities have contributed key ideas to the fusion program but will no longer be able to do so unless they can be assured of continued long-term funding and are not forced into a role of simply providing service to the national laboratories. Otherwise key personnel will be lost, competent research teams will be broken up, and university administrations will no longer encourage faculty to become involved in fusion.

Four, joint university-industry programs are both productive and very cost effective.

Five, universities are the only source of newly trained manpower for fusion and can only continue to attract and train the best and the brightest if the scope of the programs are meaningful.

Six, we must provide a mechanism for all possible participants either at national laboratories, industry, or universities, to develop and propose the most meaningful, cost-effective and relevant ideas rather than relegating industry and universities to a subservient role to the labs. If the reviews are good and an institution is judged capable of carrying out the research, it should be funded. Nobody has a monopoly on good ideas and we need the best of all of them from all sectors to solve the fusion problem.

As an example of the difficulties that have occurred in the universities, I would like to make the following points to the subcommittee concerning the University of Wisconsin's fusion program.

One, 164 persons on the Madison Campus of the University of Wisconsin are currently participating in the fusion program.

Two, three major experimental programs—tokapole/multipole, phaedrus tandem mirror, and torsatron/stellarator—comprise the Wisconsin effort along with the fusion engineering and theory programs.

Three, the university is seriously troubled about its future in this area in the wake of severe budget cuts in the tokapole/multipole and systems studies programs, and an impending termination of the Torsatron/Stellarator Laboratory even after Congress has directed that DOE provide $1.5 million in fiscal 1983 for the latter. In fact, after 7 months into fiscal 1983, the university has had to sink in $1 million of its own resources to sustain the Torsatron/Stellarator Laboratory in anticipation of receiving the $1½ million which was in the continuing resolution for DOE for fiscal 1983.

There has been no indication to date from DOE that these funds will be released. As a result, in order to keep from accruing further losses, the University of Wisconsin, April 29, placed the 20 members of the staff of the Torsatron/Stellarator Laboratory on layoff status pending resolution of this problem.

We urge restoration of the budget cuts for the tokapole/multipole and fusion engineering programs and full funding of the $1½ million in fiscal 1983 as directed by Congress, and $2 million in fiscal 1984 for the torsatron/stellarator program.

Thank you very much.

[The prepared statement of Dr. Shohet follows:]

UNIVERSITY FUSION ASSOCIATION

OFFICE OF THE CHAIRMAN
of the Executive Committee
J. L. Shohet

PLEASE REPLY TO:
Torsatron/Stellarator Laboratory
Department of Electrical
and Computer Engineering
The University of Wisconsin
Madison, WI 53706
(608) 262-1191

UNIVERSITY FUSION ASSOCIATION
Institutions of Members
Auburn University
Boston College
Brigham Young University
California Inst. of Technology
College of William & Mary
Columbia University
Cornell University
Dartmouth College
Florida Atlantic University
Florida Inst. of Technology
James Madison University
The Johns Hopkins University
Massachusetts Inst. of Tech.
Naval Postgraduate School
New York University (Courant)
Northwestern University
Oklahoma State University
Penn State University
Purdue University
Queens College of CUNY
Rensselaer Polytechnic Inst.
Smithsonian Center for Astrophysics
Stanford University
Stevens Inst. of Tech.
Syracuse University
Texas Technical University
University of Alabama
University of Arizona
University of California-Berkeley
University of California-Irvine
University of California-LaJolla
University of California-Los Angeles
University of California-San Diego
University of Colorado
University of Denver
University of Iowa
University of Illinois
University of Maryland
University of Michigan
University of Missouri-Columbia
University of Missouri-Rolla
University of New Mexico
University of Oklahoma
University of Rochester
University of South Florida
University of Tennessee
University of Texas
University of Toronto
University of Washington
University of Wisconsin
Washington University (St. Louis)

STATEMENT OF

DR. J. LEON SHOHET,

CHAIRMAN, UNIVERSITY FUSION ASSOCIATION

AND

CHAIRMAN, PLASMA COORDINATING COMMITTEE

UNIVERSITY OF WISCONSIN

BEFORE

THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

ON

THE DEPARTMENT OF ENERGY FY 1984 BUDGET

MAY 3, 1983

SUMMARY

The University Fusion Association agrees with the basic philosophy expressed in the DOE Budget Request -- support of high-risk, long-term, high-payoff programs. The subcommittee should consider the following points regarding the role of universities in fusion:

1. Universities should be considered a national resource for research; industry a national resource for product developement.

2. The present fusion budget provides only slightly more than 4% of its total to universities and has not kept pace with the scope and needs of the fusion program. This is an unconscionable loss of the great resources available in universities today.

3. Universities have contributed key ideas to the Fusion Program, but will no longer be able to do so unless they can be assured of continued, long term funding and are not forced into a role of simply providing service to the national labs. Otherwise, key personnel will be lost, competent research teams will be broken up, and university administrations will no longer encourage faculty to become involved in fusion.

4. Joint university-industry programs are both productive and very cost effective.

5. Universities are the only source of newly trained manpower for fusion and can only continue to attract and train "the best and the brightest" if the scope of the programs are meaningful.

6. We must provide a mechanism for all possible participants, either at national laboratories, industry or universities to develop and propose the most meaningful, cost-effective and relevant ideas, rather than relegating industry and universities to a subservient role to the labs. If the reviews are good and an institution is judged capable of carrying out the research, it should be funded. Nobody has a monopoly on good ideas and we need the best of all of them from all sectors to solve the fusion problem.

As an example of problems that have occurred in the universities, the University of Wisconsin would like to make the following points to the Subcommittee:

1. 164 persons on the Madison Campus of the University of Wisconsin currently are participating in the Fusion Program.

2. Three major experimental programs -- Tokapole/Multipole, Phaedrus Tandem Mirror and Torsatron/Stellarator comprise the Wisconsin effort along with the Fusion Engineering and Theory Programs.

3. The University is seriously troubled about its future in this area, in the wake of severe budget cuts in the Tokapole/Multipole and Systems Studies Programs, and an impending termination of the Torsatron/Stellarator Program even after Congress has directed that DOE provide $1.5 million in FY 83 for the latter.

4. We urge restoration of the budget cuts for the Tokapole/Multipole and Fusion Engineering programs and full funding of $1.5 million in FY 83 and $2.0 million in FY 84 for the Torsatron/Stellarator Program.

I am Leon Shohet and I am a Professor of Electrical and Computer Engineering at the University of Wisconsin. I am also the Director of the University's Torsatron/Stellarator Laboratory and the Chairman of its Plasma Coordinating Committee. I am also speaking to you today on behalf of the University Fusion Association, established in 1979, of which I am the Chairman. It is an organization of faculty and researchers whose members belong to 50 universities in the United States, all working in the area of fusion. It is my pleasure to appear before you and make a brief statement. We appreciate your efforts on behalf of the fusion community of the Nation's universities, because we know that the task of authorizing the Fusion Budget is a very difficult one.

We believe that it is important for you to gain some perspective on the university role in the Fusion Program. From this, I think, you will see just what we perceive to be the problems and opportunities for universities in Fusion. I shall first begin with the University Fusion Association.

I must point out to you that this testimony represents a summary of the opinions of many members of the UFA Executive Committee. I was impressed by the fact that the general tone of all of the comments has been very similar -- that is, it will be very difficult for universities to continue their commitment to the Fusion Program because of the lack of adequate vehicles and financial resources. It is our hope that you will assist us in contributing toward the goal we all seek -- commercial fusion power.

As you well know, the budget for fusion has grown considerably from its early years. It is important to note that a similar growth in the university activity in fusion has not taken place. For FY 1984, DOE proposes an allocation to universities of slightly more than 4% of the total fusion budget ($21 million). We think that over the years, the fraction of funds devoted to universities has decreased because of the shifting emphasis from research to relying on only a few options in the program along with rigid direction from DOE. The ever increasing programmatics have caused a number of university programs to be squeezed out, have their budgets substantially cut, or new proposals to not be funded. It is folly to terminate a $50-$100,000 per year university program to buy another pump for a beam line on a major machine at a national laboratory.

Since the bulk of the finding for fusion goes to the national laboratories, we do know that some of this funding does get "passed through" to industries and universities. However, three problems occur with this arrangement. First, laboratories often charge a fee for this pass-through, sometimes as much as 20%. Second, when budgets get tight, the first thing that gets cancelled are the outside funding projects. Thirdly, the prime contractor is the national lab and not the university or industry, so the program is directed downward to the researcher, rather than from the researcher upwards. Thus, it appears that current DOE policy is that both universities and industry act only to service the needs of the national laboratories.

This, in our opinion, is dangerously wrong. The goal of fusion research is to make fusion, not to support a group of national laboratories. Also, it is clear that the fusion problem will not be solved by this generation of researchers, and at the very least, we must recognize that the universities are the only source of newly trained manpower for fusion and can only continue to attract "the best and the brightest" if the scope of the programs are meaningful.

In addition, university activities broaden the scope of the fusion program. They provide new ideas and are more cost effective and more flexible than the national laboratories and industry. One of the major problems we see today is that, in fact, new ideas cannot be fully developed at universities. One often gets the impression that not only do national laboratories want to do the major programmatic experiments, they want to do all the experiments. Several examples can be given of programs at national labs which are of the scale and scope of those normally thought to do done at universities.

We are, never-the-less, supportive of university-industry cooperation with the national laboratories. However, except for a very few exceptions, my frank observation, covering a period of over 20 years, is that there has been very little meaningful interaction. National laboratory staff members do not seem to appreciate that a principal reason for doing research on campus is to establish and maintain a research environment into which new students can continually feed. Another reason for the problem is that national laboratory staff members generally feel that they do not need university participation. I think this results in part, from feelings of the national laboratories and the DOE Office of Fusion Energy that university staff members and students cannot get things done on schedule. Another argument frequently used by DOE and those who argue in favor of having the research done at a national laboratory is that many of the programs are large and multidisciplinary and thus unsuited for a university. These arguments have weight. However, more than one example can be cited of large, multidisciplinary, federally funded Fusion Research Programs carried on successfully by universities, when funding has been provided on a firm basis for some reasonable period of time. In the U.S. Fusion Program, the TEXT Tokamak ($10 million construction cost) at the University of Texas, the Phaedrus Experiment at the University of Wisconsin ($10 million) and the TARA Experiment at MIT ($18 million) are superb examples of the level and type of program that can be managed at universities in Fusion. In Japan, the $35 million Heliotron-E Stellarator, built jointly with industry, is now operated at Kyoto University by a staff of under a dozen people that includes several graduate students with a professor of Electrical Engineering in charge. All of these programs are very small compared to national laboratory activities, but all have contributed far out of proportion to their cost.

UFA is confident that strong, productive and cooperative research programs between the national laboratories, universities and industry can be done. University overhead rates are significantly lower than those of national laboratories; they do not have nor require large in-house construction and design groups, since much of what is done can be designed in cooperation with industry. It is also most important to again note that this research makes a significant contribution towards the training of the next generation of scientists and engineers. This constant flow of new personnel results in a stimulating environment for the development of new ideas and concepts. Examples of this include: the rebirth of stellarators in the United States, the importance of beta for fusion reactors, 3-dimensional computer codes and numerical simulation, high field tokamak operation, rf current drive, discharge cleaning, and major theoretical contributions to tokamaks and tandem mirrors.

We must provide a mechanism for all possible participants, either at national laboratories, industry or universities to develop and propose the most meaningful, cost-effective and relevant ideas, rather than relegating industry and universities to a subservient role to the labs. If the reviews are good and an institution is judged capable of carrying out the research, it should be funded. Nobody has a monopoly on good ideas and we need the best of all of them from all sectors to solve the fusion problem.

I now turn to the program at the University of Wisconsin. First, I must point out that that University of Wisconsin has been engaged in fusion research since 1962. Programs at Wisconsin have been characterized byimportant discoveries in experimental plasma research, innovative fusion reactor studies, and recently by concommitant theoretical work. Wisconsin has always been interested in unique, flexible and out-of-the-ordinary approaches, and has, at present, the greatest variety of experimental programs of any institution in the U.S., as well as many foreign laboratories. Twenty-five faculty members, 49 scientific and professional staff, and 90 graduate students, make a total of 164 persons on the Madison campus that are directly participating in this program.

Experimental facilities include the Tokapole/Multipole Laboratory, the Phaedrus Tandem Mirror Experiment, and the Torsatron/Stellarator Laboratory, as well as numerous smaller experiments. The Wisconsin tradition is for the individual faculty member or a group of faculty members to negotiate separately with the Department of Energy regarding the status of each experimental and theoretical program. We believe this permits the best interaction possible between each principal investigator and the Department of Energy. In addition, a University-wide Plasma Coordinating Committee, which is composed of faculty and scientific staff, meets several times per year regarding curriculum matters, joint organization for scientific meetings, and support for numerous individual efforts. The committee has operated in basically this format for the past 16 years, and has been used as a model of interdepartmental cooperation and operation.

I would now like to briefly describe the major experimental programs. The Tokapole/Multipole experiments have been operating on the Madison campus for more than 20 years. Figure 1 in the supplementary material shows a photograph of the Tokapole Experiment. The large octupole, also operated by this program, is the same size as the PLT Tokamak which is at the Plasma Physics Laboratory at Princeton, and was, until last December, the largest operating Tokamak in the United States. The Tokapole/Multipole Program was the first to demonstrate quiescent operation of plasmas that were thought to be unstable, along with operation at high plasma pressure. Table I shows a more extensive list of the Program's achievements.

The next program is the Phaedrus Tandem Mirror Experiment. This device, which is 32 feet long and 6 feet in diameter, has been the largest experiment constructed at Wisconsin. Its construction cost in today's dollars is approximately $10 million. The Phaedrus Experiment, currently the main back-up experiment to those at the Lawrence Livermore Laboratory, was the first to demonstrate that RF heating will work on a tandem mirror and that, in fact, only RF was needed to produce a tandem mirror plasma. Table II in the supplementary material shows a more extensive list of the Phaedrus program's achievements. Figure II in the supplementary material shows a photograph of phases.

I now turn to the Torsatron/Stellarator Laboratory. This laboratory began its operation in 1973, with the acquisition, from the Culham Laboratory in the United Kingdom, of the Proto-Cleo Stellarator. You may know that the Atomic Energy Commission abandoned stellarators in the U.S. in favor of tokamaks in 1969. As a result, there was no activity in stellarators in this country until Proto-Cleo arrived in Madison in 1974. The staff of the laboratory is most grateful to the National Science Foundation for providing the funds with which to purchase Proto-Cleo. It took great courage for NSF to fulfill their faith in the Wisconsin researchers, especially since the Atomic Energy Commission had no wish to support such a program.

The Torsatron/Stellarator Laboratory has had many achievements, including the first demonstration of Alfven Wave Heating and the first measurement of equilibrium and transport currents. In 1978 and 1979, the laboratory proposed the construction of two clearly innovative new stellarators: the WISTOR and WISTOR-U devices, the latter one of which is the basic design used for the ATF experiment, just authorized by DOE to be built at Oak Ridge. In fact, we believe that the Wisconsin program in stellarators is the main reason that there has been such a strong rebirth of stellarator interest in the U.S. today.

I am also pleased to tell you that on March 12th of this year, the University installed its latest stellarator, the IMS Modular Stellarator, which was designed and built entirely by the University of Wisconsin staff. It is the first modular stellarator in the world and should it be successful in its initial operation, we expect that all future stellarators will be built using this principle. Figure 3 in the supplementary material shows a photograph of the IMS Device, after it won the Grand Prize of Design News magazine for the most innovative engineering design of 1982.

I now turn to the Fusion Engineering Program. This program began in 1965, with experimental fusion technology studies, and was commissioned to do the first full-scale reactor study in 1971. A Wisconsin team, often assisted by industry and national laboratories, has carried out major efforts in reactor studies during the last 12 years. Many different designs have been investigated, from tokamaks and stellarators to tandem mirrors to lasers and other inertial fusion devices. To give you an idea of the scope of this program, 11 major fusion reactor studies have been completed, over 500 reports written, with more than 89,000 copies distributed world wide and over 230 articles in refereed journals have been published. The Fusion Engineering Program was one of the first to recognize the importance of RF heating in commercial Reactors and pushed the community to consider higher betas in tokamak power plants. They were one of the first to coordinate a realistic complete costing study involving industry and to design the first tokamak and tandem mirror materials testing reactors for fusion. In addition, some 16 different detailed reactor related computer codes have been developed by the Wisconsin Staff for use by industry and national laboratories. Table IV in the supplementary material shows additional "firsts" of this group.

A comparatively new development at Wisconsin has been the institution of a plasma and fusion theory program that is, of itself, not directly connected with the experimental programs. Table V in the supplementary material shows a list of the Program's recent achievements.

Thus, I think, you can see that the program at Wisconsin has been one of the major ones in fusion reasearch for a long time. Over 135 PH.D. degrees have been awarded in fusion. The University is very proud of its leadership in the fusion area.

Yet, with all of this behind us, we at Wisconsin are greatly troubled. Over the past few years, events have occurred which have given the University Administration great cause for alarm regarding the interest of the Department of Energy in fusion, both at Wisconsin, and at universities in general. I would appreciate sharing some of these concerns with you.

1. Between the years 1982 and 1983, the Fusion Engineering Program in Systems Studies has had its budget cut by nearly 50 percent and the bulk of its activities transferred to national laboratories.

2. The Tokapole/Multipole Laboratory has had severe budget cuts and is threatened with yearly extinction.

3. The Torsatron/Stellarator Laboratory has seen its favorably reviewed proposals unfunded, and instead, its ideas were given to an inexperienced group at a national laboratory. Last year, even though Congress had recognized this problem, and directed the Department of Energy to provide Wisconsin with appropriate funding in FY 83, the Laboratory has not received the funding, but instead, has been informed that DOE wishes to completely terminate the Laboratory's activities.

This is the state of affairs that greets the University of Wisconsin Administration. Personally, I have been most grateful to the University for its willingness to "go the extra mile" and to undertake a massive effort on behalf of the fusion program at Wisconsin to insure that it will remain viable.

We believe that it is not sufficient merely to recite our problems but it is imperative that we propose solutions to you. First, we believe that our problems are certainly not unique among the university fusion community. As far as the program at Wisconsin is concerned, we feel that the following must be done to sustain the program:

1. Fund, as Congress has directed, the Torsatron/Stellarator Laboratory at the level of $1.5 million in FY 83 and provide $2.0 million in FY 84 to continue its present research program and its design study, together with its 3 industrial partners, of the next generation experiment.

2. Restore the funding level for the system studies program at Wisconsin to the FY 82 level, which will permit this program to retain its well-earned right to continue providing independent and thorough reactor analyses of fusion concepts as well as to continue to provide the training of fusion engineers with a broad exposure to many aspects of the fusion problem, so that fusion can be carried to the commercialization stage.

3. Provide the FY 82 funding level for operation of the Tokapole/Multipole Program.

4. Assure the University of Wisconsin Administration that continued long-term funding is expected so that the University can rely on its status as a major fusion research center and can continue to encourage faculty and staff to work in this area.

In conclusion, both we at Wisconsin and the University Fusion Association believe that DOE should follow the philosophy expressed in the following six points:

1. Universities should be considered a national resource for research; industry a national resource for product development.

2. The present fusion budget provides only slightly more than 4% of its total to Universities and has not kept pace with the scope and needs of the fusion program. This is an unconscionable loss of the great resources available in universities today.

3. Universities have contributed key ideas to the Fusion Program, but will no longer be able to do so unless they can be assured of continued, long term funding and are not forced into a role of simply providing service to the national labs. Otherwise, key personnel will be lost, competent research teams will be broken up, and University Administratons will no longer encourage faculty to become involved in Fusion.

4. Joint university-industry programs are both productive and very cost effective.

5. Universities are the only source of newly trained manpower for fusion and can only continue to attract and train "the best and the brightest" if the scope of the programs are meaningful.

6. We must provide a mechanism for all possible participants, either at national laboratories, industry or universities to develop and propose the most meaningful, cost-effective and relevant ideas, rather than relegating industry and universities to a subservient role to the labs. If the reviews are good and an institution is judged capable of carrying out the research, it should be funded. Nobody has a monopoly on good ideas and we need the best of all of them from all sectors to solve the fusion problem.

SUPPLEMENTARY MATERIAL

TABLE I

Significant Achievements of the Tokapole/Multipole Program

1. Minimum-B stabilization of toroidal plasma.
2. Confinement clearly in excess of Bohm.
3. Influence of rotational transform on fluxtuations and transport.
4. Observation of convective cells and associated diffusion.
5. Hundred-fold increase in T_i with ICRH (to 600 eV).
6. Beta greater than (10x) MHD ballooning limit obtained.
7. Generation of poloidal divertor tokamak topology.
8. Comparison of stability of dee- and square-shaped plasmas.
9. Stable discharges with $q \approx 0.4$ obtained.
10. Demonstration of $\vec{E} \times \vec{B}$ divertor.

TABLE II

Significant Achievements Of The Phaedrus Tandem Mirror Program

1. Significant plasma heating in a tandem mirror end cell using RF (Radio Frequency waves) at the ion cyclotron frequency and at twice the ion cyclotron frequency.

2. First demonstration of plasma heating in a tandem mirror central cell using RF at the ion cyclotron frequency.

3. First experimental demonstration of MHD stability limits in a tandem mirror.

4. Production of tandem mirror configuration using RF alone, without the use of neutral beams (RF-sustained tandem mirror).

5. Density and energy buildup from combined use of RF and neutral beam injection.

6. Demonstration of electrostatic confinement of the central cell plasma in an RF-sustained tandem mirror by detailed mapping of the radial and axial structure of the electrostatic potentials in the device.

7. Production of an MHD stable axisymmetric mirror-confined plasma in the central cell without any end cells, using RF heating at the ion cyclotron frequency.

8. Demonstration of electrostatic potential modification by electron heating using RF at twice the electron cyclotron frequency.

9. Low power RF start up of an axisymmetric tandem mirror plasma.

TABLE III

Significant Achievements of the Torsatron/Stellarator Laboratory

1. First 3-dimensional MHD equilibrium calculation for stellarators
2. First use of Alfvén waves for heating plasmas in stellarators
3. First calculation that showed that tangential neutral injection would heat plasmas in stellarators most successfully
4. First use of tangential plasma injection for stellarators
5. First design of a modular stellarator
6. First construction of a modular stellarator (design won the 1982 award of Design News as the most innovative engineering design)
7. First fully three dimensional ballooning mode stability calculation
8. First analysis of particle transport in stellarators that reconciled numerical and analytic work. It showed that the transport can be much better than previously thought.
9. First direct measurement of electron heat transport in stellarators
10. First direct measurement of the bootstrap and Pfirsch-Schluter currents
11. First proof that super bananas do not exist in certain types of stellarators

TABLE IV

Significant Achievements of the Fusion Engineering Program

1. Double Null Poloidal Divertor.
2. Carbon Curtain Protection from disruptions.
3. Imbedded S/C Magnet Conductor Design.
4. Thermal Flywheel for Tokamaks.
5. Sloshing Ions in Central Cell of Tandem Mirror.
6. RF Heated commercial Tokamak Reactor.
7. First Modular Stellarator Reactor Design.
8. Nb-Ta-Ti S/C Magnets in Reactor Design.
9. Steam Coolant of Fusion Blanket.
10. 3-D Monte Carlo Neutronics of Blanket and Penetrations.

TABLE V

Significant Achievements of the Fusion Plasma Theory Program

1. Analytic calculations of barrier-trapping currents in tandem mirrors with thermal barriers.
2. Improved calculations of neo-classical transport in rippled tokamaks and stellarators.
3. Calculation of plasma flows and the bootstrap current in non-axisymmetric toroidal devices such as stellarators.
4. Investigation of rippling instabilities as a mechanism causing tokamak edge plasma turbulence.
5. Evaluation of neo-classical currents including bootstrap current in conjunction with experimental observations in the large octupole.
6. Estimation of ionization effects on self-consistent potentials in divertors.
7. Development of ray tracing codes for ECRH heating in tandem mirrors.
8. Coupling of ECH ray tracing code to transport simulation code for tandem mirrors.
9. Development of models for ICRF coupling and heating in tokamaks.

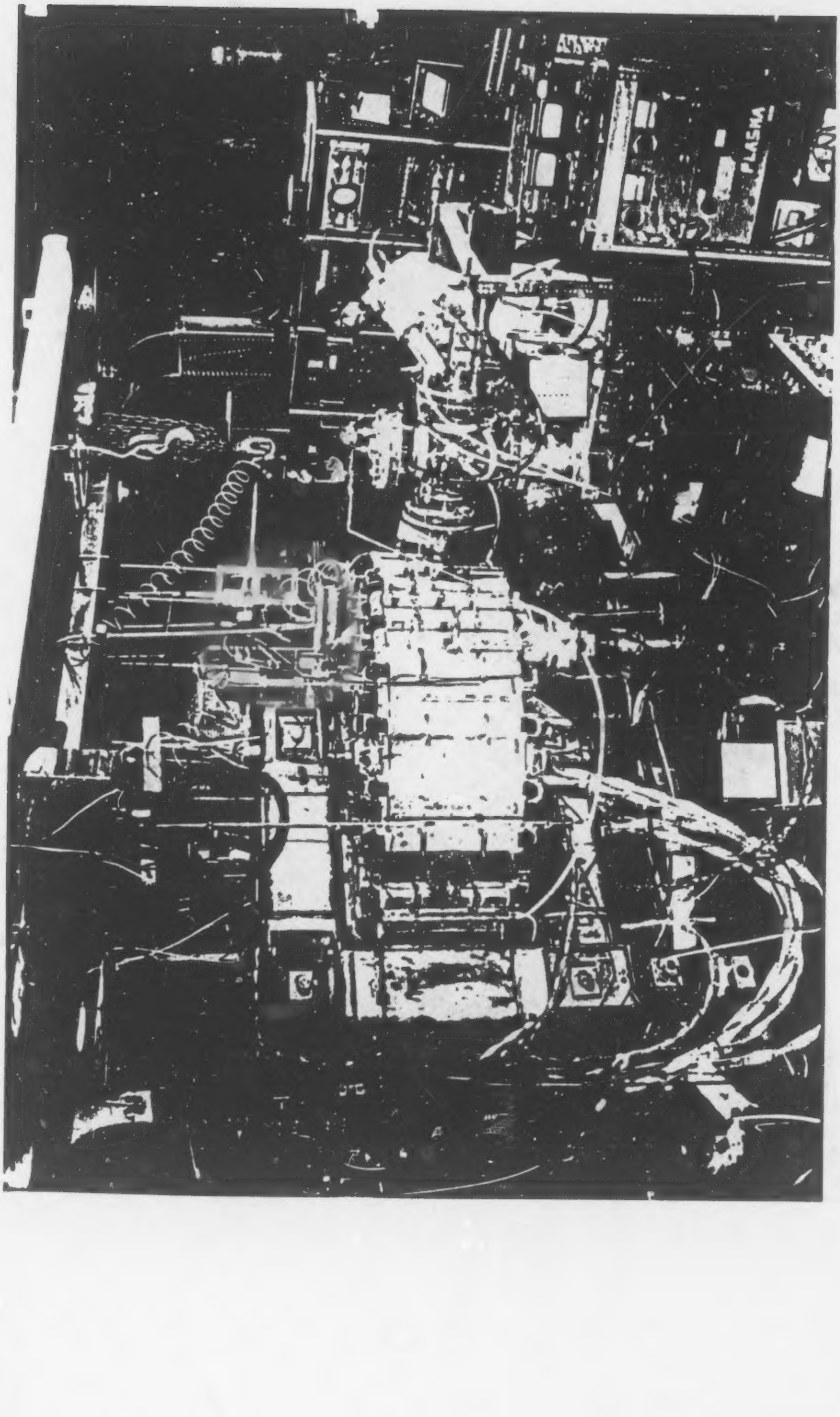


FIGURE 1

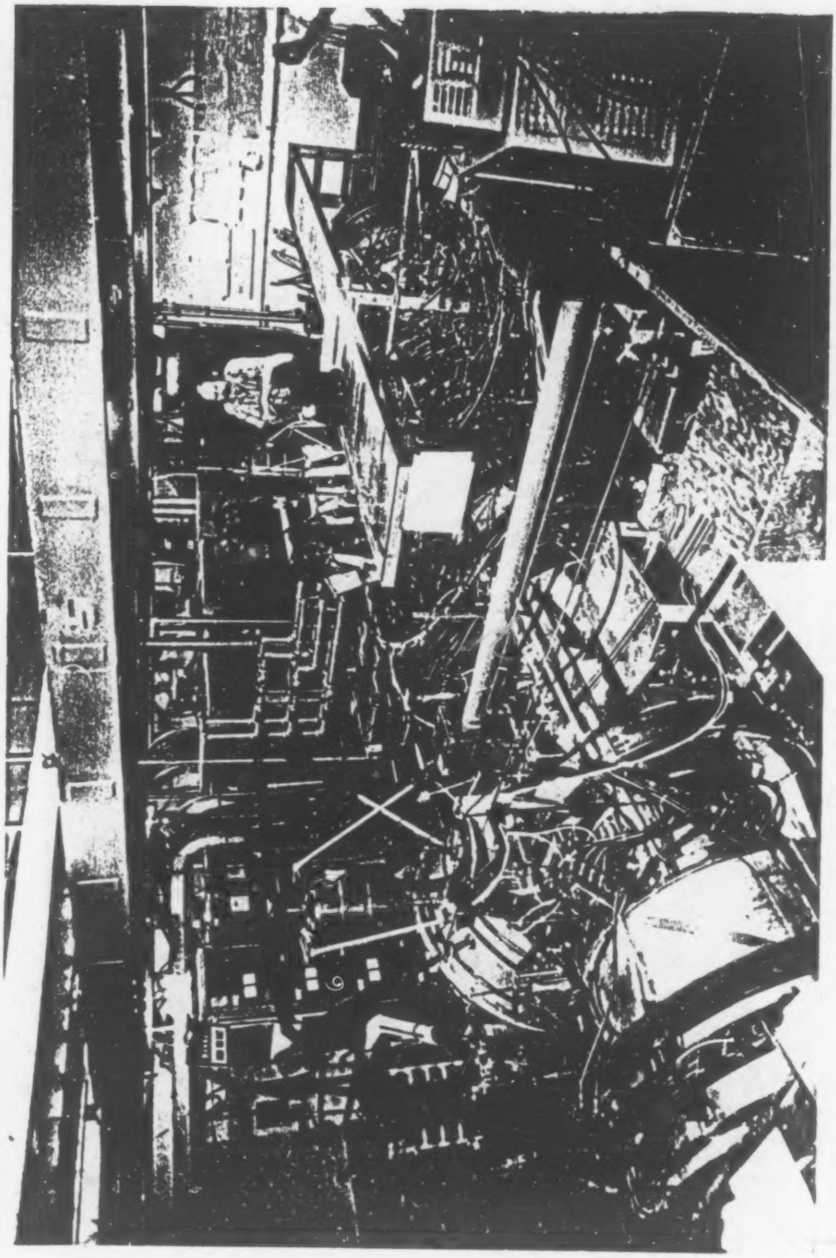


FIGURE 2

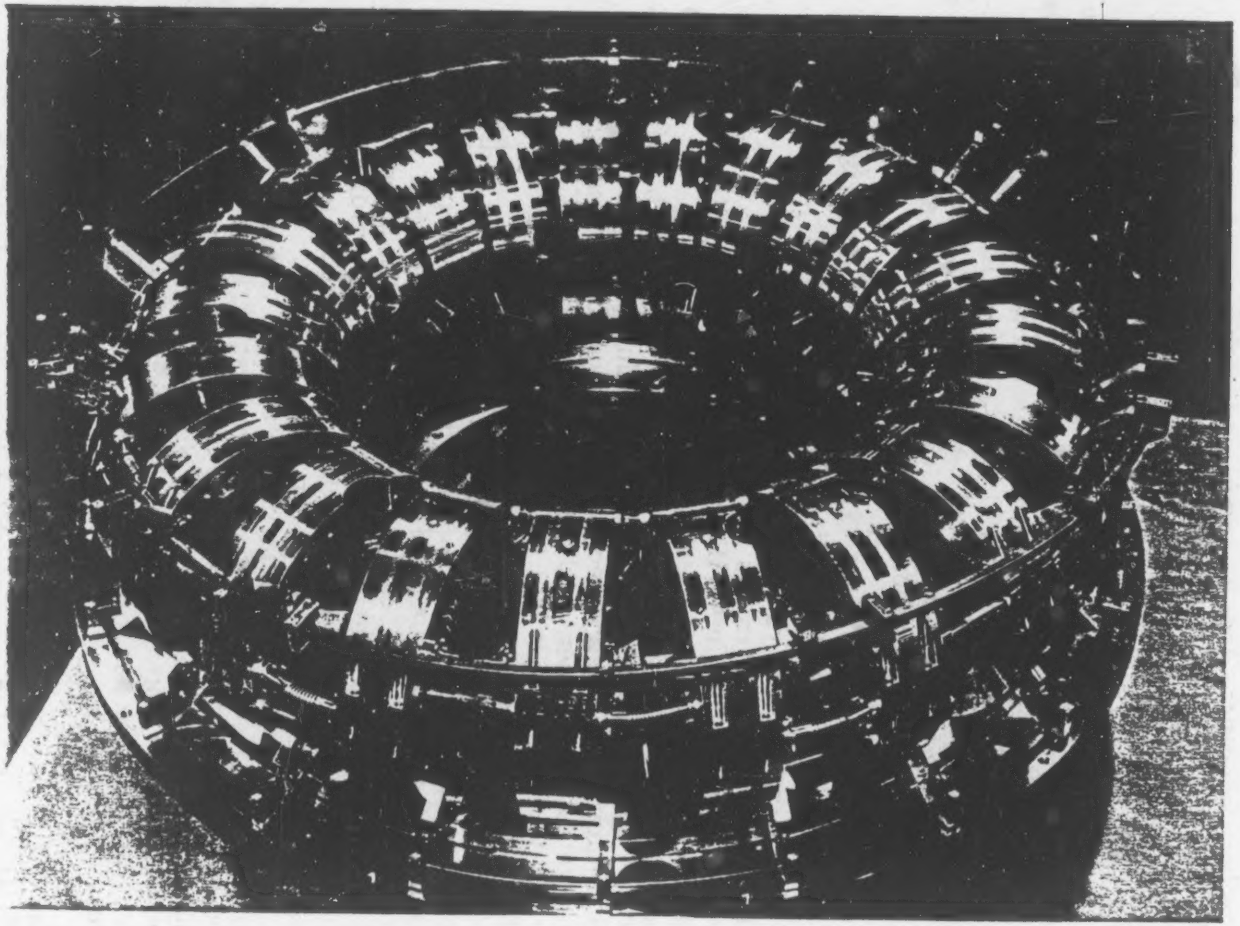


FIGURE 3

Senator MELCHER. Thank you very much, Dr. Shohet. We have a number of questions that we are going to submit, and we ask those of you on the panel to respond to the questions in writing and we will make them a part of the record along with your testimony.

We have quite a witness list yet and we are trying to get through this morning and keep your schedule, and that is why we are not going to be asking questions now, so we thank you all very much, and please give consideration to the questions that we submit.

We will have the fossil programs panel now, and we would like to introduce Dr. Bruce Stroh, Dr. Sidney Law, David Webb, Bernard S. Lee, Vincent Coates, and Carl Bagge to appear as a panel.

I would like to start with MHD. That is Vincent Coates. Will you please present your testimony?

STATEMENT OF VINCENT J. COATES, JR., VICE PRESIDENT AND DIRECTOR, MHD INDUSTRIAL FORUM

Mr. COATES. Thank you, Mr. Chairman. I appreciate the opportunity to be here. My name is Vincent J. Coates, Jr. I am vice president and director of the MHD Industrial Forum and director of the special project, the Avco Research Laboratory.

Mr. Chairman, I would appreciate it if you would be willing to accept also the statement of Mr. Jack Sherick, president of the Mountain States Energy, Inc., who is responsible for managing the component development and integration facility.

Senator MELCHER. It will be made a part of the record immediately after your statement.

Mr. COATES. Thank you. I would like to open first, Mr. Chairman, by taking this opportunity to thank you and the members of this committee for continuing not only MHD but also all the fossil energy programs—fuel cells, gasification, fluidized bed. Without the leadership and the initiative which you and your colleagues have shown, it is my belief that this country would be denied the benefits which these programs can bring.

Now I would like to summarize the testimony. First, I would like to emphasize that MHD is a conversion system. Let me give you an example. Fluidized beds are a very, very efficient means of obtaining a higher degree of heat from a given fuel. They do not by themselves, however, convert heat into electricity. The heat which they generate must be put through a conversion system in order to produce electricity.

MHD, on the other hand, removes electric power directly from the gas as it goes through the generator. It is for this reason that MHD has very high efficiencies which offer the following advantages.

In the first place, it uses coal, but at the same time will expand its life by half. It offers the opportunity for a lower cost electricity to the consumer, and its emission controls are so effective that it can go a long way toward curing the problems of acid rain which has such an unfortunate impact on health, the ecology, and even Canadian-American relations.

MHD has widespread utility support, and the testimony details that. In fact, as an appendix to that testimony you will find the resolution by the Western Utilities Conference Board in which they reaffirm their support for MHD and urge its continuation.

The question is where do we go from here? When Secretary Hodel appeared before the House Appropriations Subcommittee on the Interior, he responded to a question on that issue by saying that MHD is now ready for proof of concept. We should move forward with an engineering test facility. We in the MHD Forum agree with that, and as you will recall, at your urging and the urging of other members, we have put together a strategy which describes how MHD can be made commercial by in the earlier 1990's. I would like to emphasize that that study was not done by MHD experts, nor university people, nor even industrial people. The study was led and directed by C. T. Main, an industrial firm which specializes in designing and constructing powerplants.

In their judgment, an engineering test facility, while we prefer to call it a retrofit plant, could be made available by 1992 at a cost of about $325 million, of which we are very confident that industry would put up at least $135 million.

Mr. Sherick's testimony breaks down the contributions which industry has made over the past 20 years which totals about $50 million.

Where do we need to go immediately? Also in your testimony in the last appendix you will find a breakdown of funding options; $30 million, this program will continue to stand still. The major facilities such as the CDIF in Montana, the CFFF, the coal-fired full facility in Tennessee, will not be operating at the optimum principally because there is not enough money to buy the necessary components of fuel.

In order to get this program off dead center, $40 million is needed at a minimum. We would hope that this committee could see its way toward authorizing an amount sufficient so that the Appropriations Committee would be comfortable in appropriating at least $40 million.

Finally, the question of funding of MHD or fluidized bed or fuel cells or gasifiers is really only symptomatic of a public policy issue. The question is, Is $138 million out of a total energy budget of $11 billion sufficient amount to be spent on fossil energy? In our judgment, it is not, nor do we believe that in this 20th century, the last half of the 20th century, that it is reasonable public policy to say that the responsibility will be left entirely to industry to select those technologies which should go forward without any participation of the Government. That participation, what is required is a partnership with the Government taking an important lead.

Thank you very much, Mr. Chairman.

[The prepared statements of Mr. Coates and Mr. Sherick follow:]

STATEMENT OF
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AND
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COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
3 MAY 1983

MHD - Magnetohydrodynamics- is an advanced application of Faraday's law which states that an electromotive force is generated when an electric conductor interacts with a magnetic field.

All commercial base load electric power plants operate on this principle. MHD represents an advance in conversion technology because it converts electricity directly from the combustion products of coal. MHD derives its high efficiency by passing a coal fired plasma through a magnetic field and extracting electricity directly. This MHD portion requires no moving parts. The high temperature plasma then drives a conventional steam power plant. This combination provides very high efficiencies and very low environmental emmissions.

It should also be noted that MHD is a direct conversion system, whereas fluidized beds and, nuclear reactors are systems for converting fuel into heat which is then converted into electricity using conventional technology such as turbogenerator or fuel cells.

Of the many evaluations performed on MHD, the most extensive was the Energy Conversion Alternative Study (ESAC) performed for the Energy Research and Development Administration (ERDA) under NASA contracts, by Westinghouse Corporation and General Electric Company.

This ESAC evaluated what ERDA identified as the seven most promising conversion heat engine technologies. As in previous studies, MHD again received the highest overall rank in terms of its efficiency and environmental intrusion advantages. Not only will NO_x, SO_x and particulate levels be less than the New Source Performance Standards, but water usage, thermal pollution, and the greenhouse effect will be substantially less than with other coal burning technologies. The University of Tennessee's MHD Center has demonstrated that 90% of SO_x and that NO_x emmissions will be only .2 lbs./million BTU compared to the EPA New Source Performance Standard of .7 lbs./million BTU. As a consequence MHD could be a major contributor to solving the acid rain problem which increasingly impacts health, ecology, and Canadian/American relations.

In terms of capital cost and cost of electricity, MHD was shown to be substantially less than the ECAS referenced steam cycle and lower than the other six systems. For example, the study suggested up to a 20 percent reduction in cost of electric energy compared to a conventional coal/steam power plant. This is equivalent to about 370 million dollars (1982 $'s) in capitalized value for each 1000 MW_e plant.

A $200,000 study has been completed by Gilbert Associates for the Department of Energy in compliance with the 1981 Continuing Resolution. This study conducted by a design construction firm, specializing in the utility field, reportedly confirms these earlier studies and describes a plan for commercializing the technology.

What has the money you have appropriated for the program bought so far?

1. The results of the 1,000 hour generator test performed at Avco Everett Laboratory (AERL) in 1981 show that 8,000 hours' lifetime generators can be built and operated. Material erosion is not a problem, and the high temperature can be easily handled with conventional heat transfer technology.
2. The 20 MW coal combustor developed by TRW in California has successfully accumulated 400 hours of operation.
3. A 20 MW coal combustor developed by TRW has been integrated and tested with an MHD channel built by AERL.
4. The 50 MW coal combustor designed by TRW for use in the CDIF is scheduled for delivery early in 1984.
5. The Argonne National Laboratory in Illinois has built and successfully tested a 200 ton, 6.2 tesla superconduction magnet designed for MHD use.
6. The Coal Fired Flow Facility (CFFF), a major DoE center in Tennessee, is operating a 28 MW MHD generator with NO_x/SO_x levels reduced to well below EPA's New Source Performance Standards. (Sulphar: 90 percent below EPA requirement; NO_x: 30 percent to 50 percent below EPA requirement.)
7. The Component Development and Integration Facility (CDIF), the Department of Energy's principal test facility, located in Montana, is operating a 50 MW MHD generator and producing electricity.
8. The USAF Arnold Engineering and Development Facility (AEDC) in Tennessee has performed short-duration tests which clearly demonstrate the successful operation of near-commercial size (250 MW+) MHD channels.
9. The DC to AC inverter developed for the Electric Power Research Institute (EPRI) by Westinghouse has been successfully tested.
10. The Soviet Union is proceeding with the design and construction of a 500 MW electric power commercial utility plant scheduled to be on line in the mid 1980's.

What has been the industry support?

The private sector - industry, utilities, private electric institutes, and state and local governments have invested an estimated $50 million in the technology. Consequently there is a growing concensus within the electric utility industry, its industrial suppliers, the MHD research and development community and some segments of the Federal Government that the introduction of MHD electric power generation into utility use within a decade is a realistic goal. This results from the important advances that have been made in MHD technology over the past several years, particularly in components, and the continued confirmation of the MHD's economic and environmental advantages.

For these reasons industrial support continues to grow and the following is representative of that interest:

1. Montana Power Company (MPC) submitted an unsolicited proposal to DoE for a joint feasibility study of MHD power generation. This would lead to cost-sharing arrangements between DoE and MPC for the placement of MHD at a power plant scheduled to go on line in the early 1990's. The total contribution of MPC would be in excess of $100 million. The proposal was submitted early in 1981, but there has been no DoE response.

2. Southern California Edison independently funded the initial phases of a conceptual design for a MHD retrofit of its Etiwanda Power Station. This funding is at a level of approximately $200 thousand.

3. EPRI invested $2 million in the inverter being tested at CDIF and an additional $1 million for electric current consolidation.

4. The State of Montana has invested $500 thousand for studies of the "Utility Determination of MHD Commercialization Requirements," and the "Engineering Assessment of the Functional and Operational Requirements for a MHD Advanced Testing Systems." Twenty-two utilities participated in these studies by providing approximately $250 thousand in supporting services.

5. The Edison Electric Institute (EEI) has an MHD User's Group Committee with a membership representing all of the major utilities using fossil fuel.

6. The Advisory Board of the MHD Industrial Forum includes distinguished leaders representing the electric utility industry, utility component manufacturers and suppliers, and engineering, design and construction firms.

7. The Committee which prepared the MHD Industrial Forum's "A Strategy for the Early Commercial Development of MHD for the Generation of Electric Power" which shows a means for commercialization of MHD in the early 1990's, included representatives from the electric utilities industry and engineering and construction firms serving the utility industry.

8. Western CEO Utilities Conference affirms support for MHD and rejecting ERAB report by resolution (attached).

This utility interest has been encouraged by the EPRI "Operational Analysis of Open Cycle MHD" performed by Westinghouse, dated July 1980, which state that: "These results on a national level show that MHD has the potential to capture as much as 42 percent of the total coal unit additions projected to be added between 1995 and 2000." Also by the "Comparative Study and Evaluation of Advanced Cycle Systems" conducted by the General Electric Company for EPRI, dated February 1978, contains various figures showing that MHD power plants could capture over 40 percent of the utility market after the year 2006.

How should we continue?

The immediate need is to begin to accellerate the program which has been essentially in a holding pattern for the past year.

The $30 million FY83 budget has not been sufficient to perform vital developmental and engineering tests. For example this year the Coal Fired Flow Facility (CFFF) in Tennessee ran only 23 hours. Procurement of essential equipment and components for the CFFF has been delayed. No coal fired generator operation will be performed in FY83 at Avco. The CDIF in Montana operated for only 6 hours. Funding limitations have delayed completion of the 50MW coal combustor, resulting in an indefinite postponement of its installation in the CDIF, originally scheduled for early this year. Likewise control circuitry scheduled for delivery to the CDIF in September has been delayed. Almost no work has been done on the Advanced Flow Train because of funding problems. In order to correct these difficiencies and begin to make progress again, a budget of $40 million is required in FY84 (attachment 2).

At the urging of many members of Congress the MHD Industrial Forum organized a panel of experts representing the utilities, design and construction firms and representatives of the MHD R & D community. To develop the "Strategy for Early Commercial Development of MHD for the Generation of Electric Power." (The executive summary is attached.)

Unlike previous proposals which called for a completely new power plant to be operational in the late 1990's, this Strategy centers around a "retrofit" e.g., the addition of an MHD unit to an existing coal burning power plant. Since an MHD plant includes a conventional steam turbine, the retrofit MHD plant will utilize the existing turbine generator, cooling system, support functions and personnel on an operating site. In addition to being significantly less costly than a completely new plant, the retrofit will result in about a 50 percent increase in power generation capability.

The retrofitted plant would be operational by 1992 with a nominal output of 120-130 megawatts of which 50 megawatts would be obtained from the MHD cycle. This size is optimum to provide all the reliability and operational data required by the utility industry for final commercial evaluation and at a cost far less than a full-sized demonstration plant but with more testing and operational flexibility. This option also reduces environmental impact studies and permit requirements.

The initial retrofit may not actially be commercially viable but would provide the basis for commercial viability in the shortest practical time span through a consortium effort involving utilities, industry and the government. One consortium possibility is:

- a utility industry to provide the retrofit site, program management, and operating personnel, with other utilities assisting the funding of commercially available component;
- private industry to provide component design, and fabrication, and engineering services at minimum profit;
- the Federal Government to continue funding the MHD program and to furnish components resulting from this program;
- the State/Local Governments to assist in licensing and environmental studies to minimize delay and cost.

The total cost of the retrofit is estimated at $325 million. The initial phase of the program will explore various funding possibilities for the participants. A funding possibility is for the Government to furnish those components which will come from the MHD development program and for the private sector to furnish those components which are commercially available.

The Strategy suggests selecting a retrofit site while making financial arrangements in 1983 and 1984. Detailed engineering would start early in 1985 followed by the procurement of major components, and construction would start by 1986. Since the retrofit is the first of its kind, four years are allowed for construction. The MHD segment would be ready for test operation in early 1988, allowing most of 1988 and 1989 for modifications that may be necessary prior to retrofit initial operation in late 1989 with expected utility operation by the end of 1990.

It should be understood that the retrofit approach does not eliminate the need for research and development. Indeed, to achieve its maximum promise, MHD like any other advanced technology, will require a continuing research and development program well beyond its initial commercial operation.

It is the opinion of the Forum that private funds will be forthcoming when the industry sees that the government is committed to a well-defined program within a clearly-defined time schedule. Several utility companies are already investigating possible MHD retrofit alternatives. The Montana Power Company earlier submitted a proposal to DoE to cost share in an MHD assumed program.

Clearly in this present economic climate budgetary considerations must be taken into account, but is a national energy budget that devotes only $135 million for coal R & D good national policy for the development of the nations most abundant fuel resource.

Is it good public policy to virtually ignore coal technology development while we continue to depend upon fuel imports. In reality the DoE proposed MHD termination is only symptomatic of an energy policy that is not responsive to national needs. In our judgement the public interest requires a balanced energy R & D program that includes coal, oil, gas, nuclear, fuel cells, solar and other advanced and innovative technologies in a program that is financed to reflect the national need and interests.

The Government must also take the lead in this effort since it long ago assumed primary responsibility for high technology research and development. Neither MHD nor any other advanced energy technology will acheive commercial use without Government support and leadership.

ATTACHMENT -1-

RESOLUTION

The Western Utilities CEO Conference

The Western Utilities CEO Conference, meeting in regular Session on January 13, 1982, unanimously adopt the following resolution, and instruct the organization's Chairman to promtly convey this resolution to the attention of the members of the Energy Research Advisory Board of the U.S. Department of Energy in the most prominent and urgent manner available:

"WHEREAS, the Western Utilities CEO Conference is composed of Chief Executive Officers of all the electric utility companies serving the 13 western states, joined together to foster the mutual interests of America's electric power consumers and the electric utility industry, particularly in the western part of the U.S. and,

"WHEREAS, the efficient, flexible and cost effective generation and distribution of electric power is a vital component in the industrial and defense economy and capability of the U.S., and,

"WHEREAS, the generation of electric power in the U.S. is seriously impacted by inflation, environmental restrictions, government regulation, high interest rates, high equipment costs, and a dearth if technology options, and,

"WHEREAS, the use of this nation's immense coal resources for electric generation — given appropriate technology for coal's clean and efficient use — represents the feasible, long term energy option, and,

"WHEREAS, the Energy Research Advisory Board (ERAB) of the U.S. Department of Energy has recommended the virtual elimination of federal support for Research and Development of coal-using energy conversion technology; therefore,

"BE IT RESOLVED — that the Western Utilities CEO Conference strongly supports a national commitment to the use of coal for electric power generation in the U.S., as being in the best interests of the nation, electric power consumers, and the electric utility industry. The Western Utilities CEO Conference believes that magnetohydrodynamics represents one of the most efficient methods of utilizing our vast resources of coal for the generation of electric power, with greatly reduced environmental problems. We, therefore, urge ERAB to reconsider its no-funding recommendation on coal energy conversion research, and we recommend in particular that the MHD program receives continued support.

WESTERN CEO UTILITIES CONFERENCE

Arizona Public Service Company
Idaho Power Company
Montana-Dakota Utilities Company
Nevada Power Company
Pacific Gas and Electric Company
Pacific Power and Light Company
Portland General Electric Company
Public Service of New Mexico
Public Service of Colorado
Puget Sound Power and Light Company
San Diego Gas and Electric Power Company
Sierra Pacific Power Company
Southern California Edison Company
Tucson Electric Power Company
Utah Power and Light Company
Washington Water Power Company

ATTACHMENT II

FY 1984 MHD FUNDING OPTIONS

$30 MILLION (FY 83 PROGRAM)

FUNDED

- 50 hrs* of oil fired power generating tests with CDIF and delivering electric power to the Montana Power Grid using EPRI MHD inverter developed by Westinghouse
- Electrode and channel development using oil fired 20 MW_t generator at Avco
- CDIF achieved 1.67 MW of power (rated design point 1.69 MW)
- Fabrication and construction of superheater at CFFF
- Analytical study of bag house and precipitator - Univ. of Tennessee
- SO_x/NO_x control test completed
- 80 hrs* of slag/seed interaction experiments at Univ. of Tennessee
- 23 hrs of CFFF boiler operation for thermal and stoichiometry tests (2000 hrs required before scale-up)
- Subsonic channel testing
- Power conditioning testing

NOT FUNDED

- Equipment component procurement for CFFF delayed
- No coal fired MHD generator operations
- 50 MW coal combustor completion by TRW indefinitely delayed
- Control circuitry equipment delivery to CDIF postponed until FY 84
- Advanced flow train work essentially halted
- Delivery of coal feed equipment to CDIF delayed
- 120 hrs of scheduled 200 hr slag/seed interaction studies at Univ. of Tennessee have been postponed
- Maintain only essential core people

*Schedule to be achieved by year end

$40 MILLION

- Complete coal feed system at CDIF
- Initiate and complete fabrication of 50 MW_t coal combustor
- Install 50 MW_t coal combustor in CDIF and begin checkout
- Initiate design and fabrication of MHD channel for coal fired operations
- Install circuitry and current consolidation control in CDIF
- Initiate coal fired testing at 20 MW_t
- Procure and install bag house and electrostatic precipitator at CFFF
- Procure seed regeneration system components for CFFF
- Proceed with Advanced Power Train (Phase I)
- Initiate development of Mobile Instrumentation Lab. at Univ. of Mississippi. Continue diagnostic work
- Continue other engineering development activity
- Strengthen core personnel group

$50 MILLION

- Initiate long duration coal fired operations at CDIF using inverter and delivering power to utility grid
- Initiate long duration seed recovery tests at CFFF
- Long duration testing of 50 MW_t coal combustor
- Begin bag house and electrostatic precipitator operation
- Long duration generator testing at 20 MW_t with coal
- Complete development of Mobile Instrumentation Lab.
- Complete Phase I and initiate Phase II of Advanced Power Train
- Complete or accelerate tasks shown under $40 M level
- Initiate retrofit program
- Expand core people and begin to train new people in MHD technology

Executive Summary

A Strategy for the Early Commercial Development of MHD for the Generation of Electric Power

February 1983

Prepared Under the Direction of
THE MHD INDUSTRIAL FORUM
Suite 805, 1725 Desales Street, NW
Washington, D. C. 20036

General

Magnetohydrodynamics (MHD) is an advanced power generation concept that can produce electricity from coal at the highest possible efficiency and the least possible impact on the environment.

The current MHD development program is directed toward the step-by-step development of MHD with the intent to place an MHD power plant in operation in the late 1990's. The MHD Industrial Forum has reviewed this program and recommends a strategy intended to place a plant into operation on a shorter schedule and at a reduced cost. The strategy centers around a "retrofit" or the addition of an MHD unit to an existing power plant. Since an MHD plant includes a conventional steam turbine, the retrofit MHD plant will utilize the existing turbine-generator, cooling system, and be at an operating site for which most support functions and personnel are already present. In addition to being significantly less costly than a completely new plant, the retrofit will result in increased power generation capability since the existing steam turbine-generator output will remain the same. The initial retrofit may not actually be commercially viable but would provide the basis for commercial viability in the shortest practical time span through a consortium effort involving utilities, industry and the government. One consortium possibility is for:

° A utility to provide the retrofit site, program management, and operating personnel, with other utilities assisting the funding of commercially available components;

° private industry to provide component design, and fabrication, and engineering services at minimum profit;

° the Federal Government to continue funding the MHD program and furnish components resulting from this program;

° the State/Local Governments to assist in licensing and environmental studies to minimize delay and cost.

MHD has been considered a promising alternative for the more effective use of fossil fuel for some years. A few years ago, it became clear to some of the electric utilities that the technology had advanced far enough that some specific application should be made. In 1980, a utility group met to start work on the technology application effort.

The important thrust of this program is seen by the utilities group as being the retrofit of existing power plants. Oil-fired and coal-fired plants are both candidates. Several utilities have developed conceptual retrofit designs, and the utility MHD Users Group is working on the identification of power plants that could be candidates for retrofit. At the same time, the Users Group is working with the Pittsburgh Energy Technology Center to design the components of the Federal programs necessary for the first retrofit plant. The interest in such a retrofit is because of the improved efficiency, reduced site problems, oil replacement, the promise of acceptable environmental impact, and reduced capital demand. A retrofit would meet many requirements even though it did not meet the ultimate potential of a final system.

The long-term future does demand a continuing research and development program but success of the retrofit would provide an industrial base from which additional improvements can be derived. These improvements, coupled with research and development, are the approach most likely to lead to the most efficient fossil fuel power plant at the least development cost.

MHD Concept

In this concept, coal is burned using oxygen enriched, preheated air to obtain a high temperature. A small quantity of potassium carbonate is added making the resulting combustion gas electrically conductive. This gas is passed through an MHD channel surrounded by a superconducting magnet resulting in the production of electric power. The gas which leaves the MHD channel is still very hot, and goes to a heat recovery boiler which generates steam to drive a conventional steam turbine-generator for the further production of electric power. Using current technology, an MHD plant would have an overall thermal efficiency of about 40-50 percent as compared to about 32-34 percent for a conventional steam plant and will require only about 75 percent of the fuel. There is the longterm potential for increasing the thermal efficiency of an MHD plant to about 50 percent, which would reduce fuel requirements to less than two-thirds that of a conventional plant.

The potassium combines with any sulphur in the coal to form potassium sulphate which can be removed with the coal ash prior to discharging the flue gas to the environment. A 95 percent or greater sulphur collection efficiency is expected which equals or exceeds the best SO_2 removal efficiency using current scrubber technology for conventional plants. When combined with the lower sulphur input (less fuel used), an MHD plant can greatly reduce the amount of sulphur compounds discharged to the environment. The potassium sulphate is processed back to carbonate for reuse.

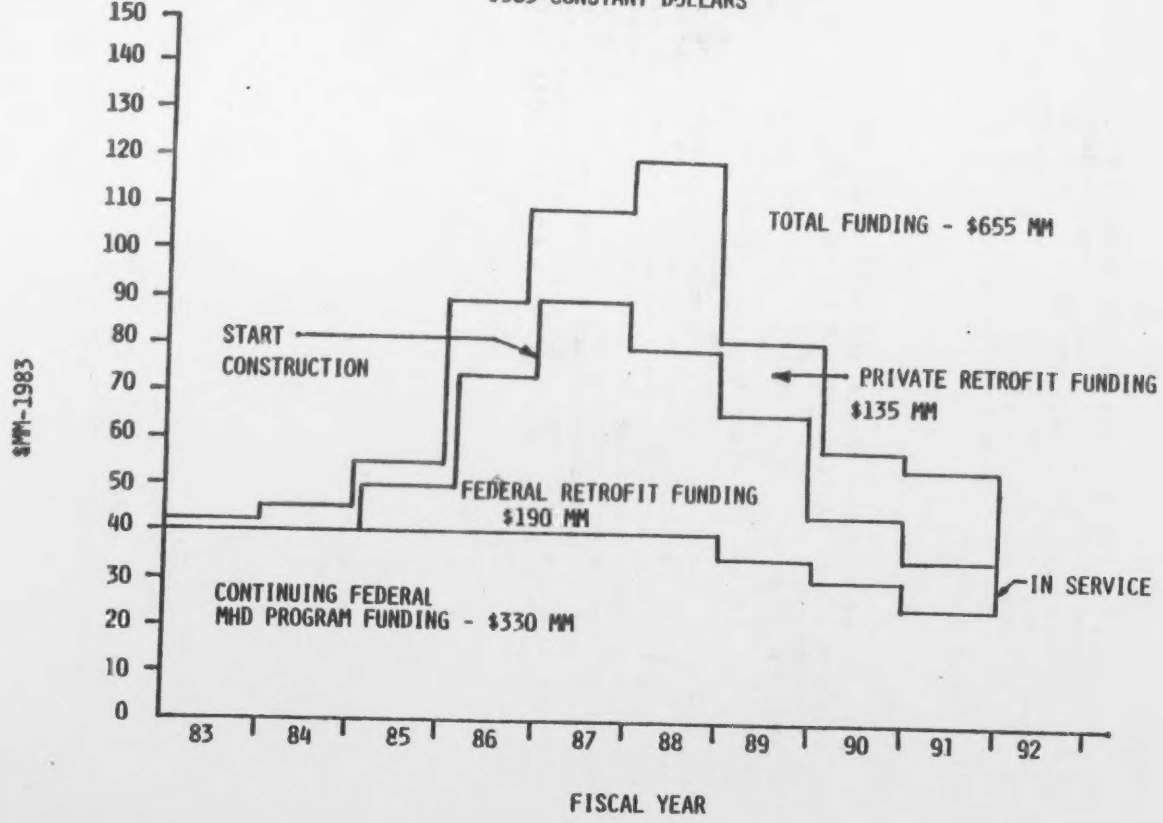
Funding

The 1983 cost of the retrofit is estimated at $325 million. This is in addition to continued funding of the present MHD development program at a level of $40 million through 1988 and reducing $5 million per year thereafter which represents a total of $330 million through the end of 1991. The attached cash flow chart illustrates the estimated funding for the proposed MHD development program.

Schedule

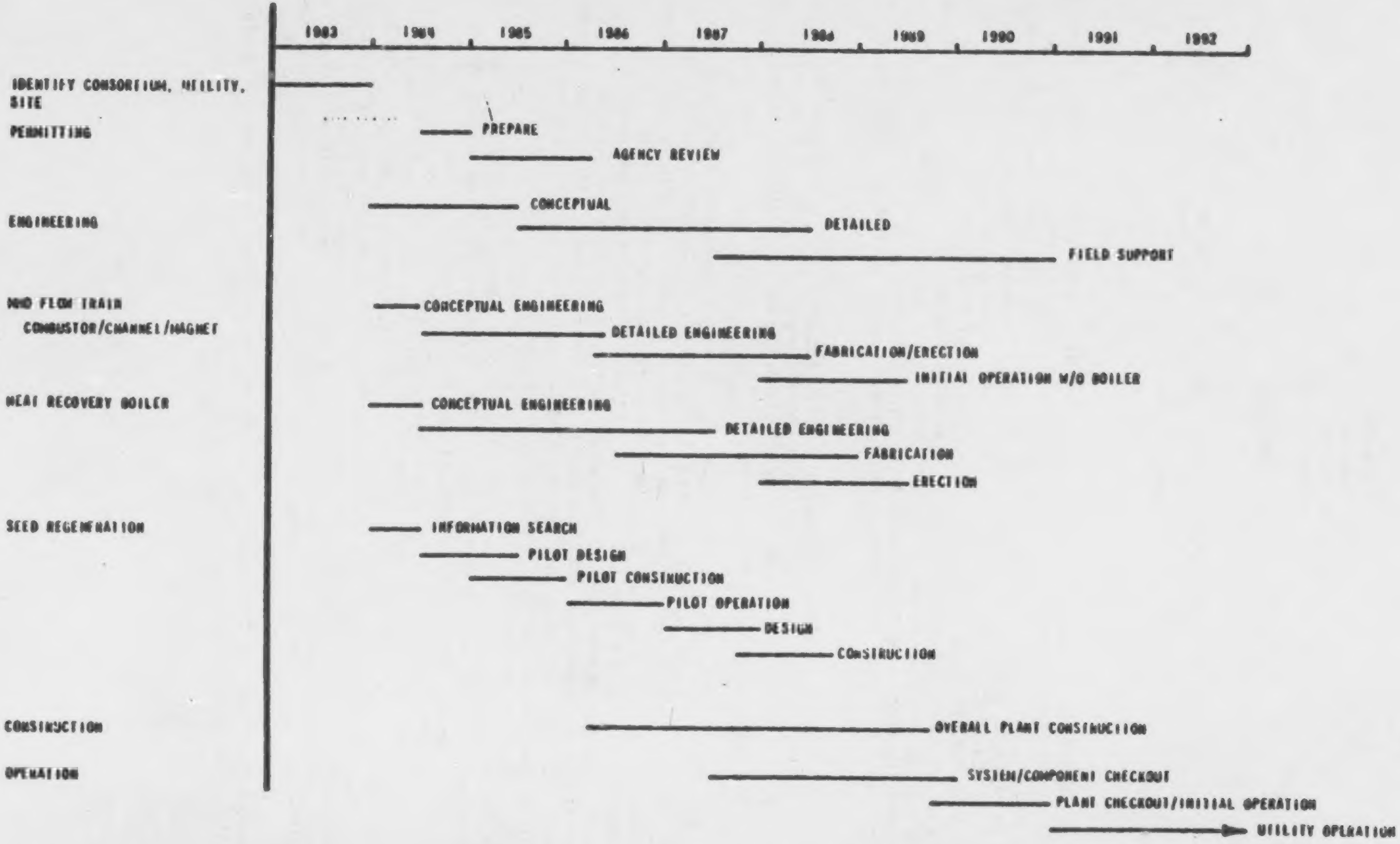
It will be necessary to select and confirm a retrofit site and obtain firm financial arrangements for the entire project prior to the commitment of any major expenditure. 1983 and 1984, are allowed for this activity. Detailed engineering would start early in 1985 followed by the procurement of major components, and construction would start by 1986. Since the retrofit is the first of a kind, four (4) years are allowed for construction. The MHD flow train consisting of combustor, channel and magnet would be ready for test operation in early 1988, allowing most of 1988 and 1989 for modifications that may be necessary prior to retrofit initial operations in late 1989. The heat recovery boiler is a major original engineering effort and represents the critical path. Plant checkout and initial operations are shown from the middle of 1989 into late 1990. Initial operation of the retrofit would start in late 1989 with expected utility operation by the end of 1990.

ESTIMATED
FUNDING FOR MHD DEVELOPMENT PROGRAM
1983-CONSTANT DOLLARS



MHD RETROFIT SCHEDULE

5



Statement of
J. M. Sherick, President
Mountain States Energy, Inc.
Butte, Montana

To The

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
3 MAY 1983

I am pleased to submit this testimony in support of the continuance and increased support of magnetohydrodynamics (MHD) development. In this testimony I will show that: (1) There is a need for the development of fossil energy technology to meet our continued energy demand in this country; (2) MHD offers the greatest potential of the other coal conversion technologies being considered; (3) There is and has been substantial non-federal government involvement in MHD development to date, but continued federal investment is necessary for the development to proceed; and, (4) A workable strategy for further development has been prepared and presented to the Congress.

Through these points I hope to lay the basis for a continued U.S. Government, DOE funded program of nominally $40 million in FY-84 and continued support of the Advanced Test System as outlined in the Industrail Forum Strategy.

Coal, as in the past, continues to be the dominanat fuel for electric power generation in the United States. Today approximately one-half of the electric power produced in this country is produced in coal-fired power stations. This percentage is expected to increase significantly in the future. It is estimated that between 1990 and 2010, approximately 4000,000 megawatts of additional electrical generation capacity will be required to replace older units being retired and to meet the increasing demand for electrical energy. Three quarters of this capacity is expected to be generated in coal burning power plants. With this increased reliance on coal, it is important that this new generating capacity utilize the cleanest, most efficient, cost-effective technologies available. Environmental problems associated with the utilization of coal, such as acid rain, CO_2 emissions which contribute to the greenhouse effect, solid slag waste, thermal pollution and others, can be mitigated through the use of these advanced technologies. Furthermore, these advanced technologies offer direct and significant cost savings to the utility rate payers and conserves valuable, limited, natural resources. It makes sense to invest in the development of a more efficient technology since the payback potential is so great; Increased efficiency resulting in 5 mills lower electricity cost would for the period 1990 to 2010, save utility rate payers about $90 billion.

Of the advanced coal conversion technologies currently under development, and this includes molten carbonate fuel cells, magnetohydrodynamics, high temperature gas turbines, and pressurized fluidized bed combustion, MHD in my opinion offers the greatest potential to favorably impact our energy future. Only MHD offers direct conversion of coal to electricity at efficiencies near or greater than 50% in an acceptably clean manner.

The MHD process has a broad range of application compared to other advanced coal to electricity conversion technologies currently in the developmental stage. Although development of MHD has been focused primarily on coal-fired open cycle MHD for large base load power generating stations, other energy sources, configurations, and applications are possible. These include a large potential for cogeneration application of MHD in electrical energy intensive and high temperature industrial processes, as well as applications in the defense area. In addition to all of these advantages, only MHD offers long term potential for application with advanced power conversion systems such as fusion, and spinoffs which includes superconducting, cryogenic, and magnetic applications.

MHD research in the U.S. has been largely viewed as a program funded entirely by the federal government. Such is not the case. Private industry was involved in MHD research long before the federal government established the current R&D program in the Department of Energy. Private industry and state government's investment in MHD has exceeded $50 million to date. A summary of private industry investment in MHD research is given in Attachment 1. While industry's investment in MHD research has been significant, industry is incapable of developing the MHD technology by itself. Such a development program must involve the federal government. Industry has indicated willingness to be an active partner with the federal government in MHD research. The "Strategy for Early Commerical Development of MHD for the Generation of Electric Power" recently developed by the MHD Industrial Forum, an industry based group, outlines in broad terms how the federal government and private industry can work together to develop the MHD technology to a point of determination of commercial readiness. Attachment 2 is the Executive Summary of this strategy.

The State of Montana in combination with private industry has already taken an initial step required in the implementation of this strategy. The State of Montana through the Department of Natural Resources and Conservation has funded a project to assess the retrofit potential of MHD to an existing utility steam electric power plant. The first phase of this project defined from the utilities perspective the performance requirements for an advanced MHD test system including topping and bottoming cycles retrofitted to an existing plant. The second phase of this project incorporates these performance requirements in an Engineering Assessment and includes a screening of the utility industry to select candidate sites for installation of this facility. The State of Montana will invest $500,00 in this project with utility and industry contributions adding about another $250,000. The project is scheduled for completion at the end of June 1983.

The potential offered by the MHD technology to improve the performance of coal-fired power generating stations, and its more long term potential to work in combination with other advanced technologies such as fusion, makes its continued development essential. While private industry has shown a willingness to participate in the development of MHD, it is clear that private industry cannot by itself finance the necessary development program. The MHD Industrial Forum Strategy is unique in that Congress has before it the estimate of what the total obligation to fully take this technology from its present status to commercial readiness. The federal government must continue to actively support the MHD technology development if it is to become a viable energy option for the future.

ATTACHMENT I

INDUSTRY AND STATE GOVERNMENT INVESTMENT IN MHD

To date, industry and state governments have invested over $50 million in research and studies on the MHD technology. These investments are summarized below:

I Utility Industry

A. Electirc Power Research Institute (EPRI)

Since 1974 EPRI has funded $8-$10 million in various studies on MHD. In addition, EPRI funded the design, construction and installation of the $2 million inverter at the CDIF. EPRI has budgeted $1.5 million for MHD over the next five years.

B. Edison Electric Institute

The 21 member EEI Task Force and MHD (Utilities MHD Users Group) has been meeting twice yearly on MHD for the past three years. In addition, the Task Force members have participated at their own expense in the studies sponsored by the State of Montana DMRC. Contribution of engineering services and travel by EEI Task Force members and the utilities is estimated to be about $250,000 to date. The project is still underway.

C. Southern California Edison

SCE has funded $600,000 - $700,00 of MHD work during the past five years. In addition, an estimated $350,000 will be spent in FY-83.

D. Montana Power Company

The MPC has actively supported the MHD technology for a number of years. MPC has submitted proposals to the DOE for a cooperative project at their planned Salem Plant and is one of the utilities that would be very receptive to participating in the MHD Industrial Forum concept.

E. American Electric Power Services Co.

In the 1960's, AEP supported approximately $1 million of MHD work.

II State Governments

A. The State of Montana through its Department of Natural Resources and Conversation (DMRC) has funded $500,000 to conduct an engineering assessment of retrofitting MHD. In addition, utility contribution to this project as noted in I.B. has been in the order of $250,000. The project is still underway.

B. State of Tennessee

The State of Tennessee provided a $2.2 million building to the University of Tennessee Space Institute of which one-half is dedicated to MHD research.

C. Others

Several states other than Montana have expressed interest in supporting coal technologies. Specifically, the State of Alaska has been considering funding studies in MHD application in Alaska.

III Industry

A. Reynolds Metals Company

Over the 10 year period, starting in the mid 1960's, Reynolds Metal invested approximately $5 to $6 million in MHD research.

B. TRW Incorporated

To date, TRW has invested about $8 million in MHD including about $3 million in their MHD combustor test facility.

C. AVCO

AVCO has been involved in MHD research for over 25 years. During the 1960 to 1970 time period, AVCO with a group of utilities invested over $10 million in MHD research.

D. Westinghouse

Westinghouse has been involved in MHD Research since 1939 and has invested $15-$20 million in research on the technology since then.

E. General Electric

In the 1950-1960 time period, General Electric invested $1-$2 million in MHD research.

F. University of Tennessee Space Institute

UTSI has invested about $500,00 in facilities for MHD research plus, as noted in II.B., the State of Tennessee provided a $2.2 million building about one-half of which is dedicated to MHD.

Senator MELCHER. Thank you. I don't know why it is so tough to get R&D for basic work. I understand there is 27 billion dollars' worth of R&D work for the Defense Department. They anticipate that much or a little bit more for next year. You would think they could find a couple hundred million.

It is regretful that we can't get some basic R&D where we need it. We will see what we can do.

I think we ought to call the gas people next to testify. Bruce Stroh from the American Gas Association, and then there are two more--the Gas Research Institute, and the Institute of Gas Technology. I think we will just have the three of you in order.

Mr. Stroh.

STATEMENT OF BRUCE STROH, MANAGER, TECHNOLOGY DEVELOPMENT, AMERICAN GAS ASSOCIATION

Mr. STROH. Thank you, Mr. Chairman. On behalf of AGA, I thank the committee for the opportunity to testify. I have submitted my testimony for the record, and I would like to just in a few minutes briefly summarize that text.

It is certainly a privilege for me to be here. AGA urges this committee to assure an appropriation of no less than $146 million for gas-related research and development in fiscal year 1984. AGA agrees with the administration that the Federal Government should fund long-term, high-risk R&D which cannot be undertaken by the private sector alone. That is why we believe our recommendations are consistent with this philosophy and have the potential for very high payoffs.

The gas industry believes there is a role for federally funded gas research. Results have shown that the Government and industry can work together effectively. AGA believes that one of the criteria for Federal R&D funding should be based on the energy source's contribution potential to the Nation's long-term energy needs, yet the administration's fiscal year 1984 budget proposal, if adopted, would devote a high proportion of funds to nuclear energy which unlike gas will provide a low proportion of primary energy consumption by the United States in the foreseeable future. Even though nuclear power consumption is quite low compared to other fuels, the Department of Energy budget proposal allocates over 50 percent of the R&D funds to this area.

On the other hand, fossil fuels supplies over 90 percent of the U.S. energy needs but receives only 6.1 percent of the R&D funds of the administration's budget proposal. Taking a layman's view, one may wonder why the Government wants to spend more than twice as much on research to dispose of the waste product on one energy technology over the amount to be spent on all fossil technologies combined. This is not to say that nuclear research is not important. It is simply one illustration of the funding imbalance that exists with respect to all forms of energy research.

The recommendations contained in this testimony provide a better balance of R&D funding with respect to fossil fuels and gas-related research, and in particular one of the often misunderstood facts regarding research is that it takes many years from the time research begins until the commercialization of the results. Therefore, research must be in place now to meet long-term energy needs.

A common mistake is for the timing of research to be out of phase with the need. Even so-called short-term research takes several years to complete, and requires careful planning and consistent support. The yo-yoing of the DOE's fossil budget picture has to have an adverse effect on long-range planning, program staffing, and project success. Gas research programs should not have to be reactive to energy price or budget fluctuations.

All of the areas recommended for funding in this testimony fit the administration's criteria for long-term, high-risk research and require investments beyond the capabilities of the private sector. They were not arrived at casually but rather were the result of careful consideration of the highest priority needs of the industry. The recommendations for funding are as follows—for coal gasification, $50 million; for unconventional gas, $32 million; for gas-fired fuel cell technology, $20 million; for conservation utilization research, $19 million; for biomass, $20 million; and finally, for LNG safety, $5 million.

In summary, AGA believes these recommendations are for long-term, high-risk projects and will lead to the successful completion of current programs that would not otherwise be funded by the private sector.

Congress can provide a more balanced R&D program than the administration's budget proposal by appropriating funds in line with these recommendations.

Further, all of the funds which AGA recommends will be applied to research projects that will improve current technology, at the levels required to meet the Nation's future energy needs. Since gas represents a source of energy for millions of consumers, the supply benefits of gas-related R&D funding can be far reaching.

Thank you very much.

[The prepared statement of Mr. Lawrence of the American Gas Association follows:]

STATEMENT OF

GEORGE H. LAWRENCE, PRESIDENT
AMERICAN GAS ASSOCIATION

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ON THE DEPARTMENT OF ENERGY FY 1984 RESEARCH
AND DEVELOPMENT BUDGET

MAY 3, 1983

INTRODUCTION

Mr. Chairman and Members of the Subcommittee:

On behalf of the American Gas Association, I thank the Committee for this opportunity to testify. A.G.A. is composed of nearly 300 natural gas distribution and transmission companies serving over 160 million consumers in all 50 states.

A.G.A. urges this Committee to assure an appropriation of no less than $146 million for gas-related research and development in FY 1984. Adequate funding can be justified by scrutinizing the R&D funding criteria, the benefits of gas-related R&D, and the need for an R&D approach which strikes a fair balance between various energy sources.

FUNDING CRITERIA

A.G.A. agrees with the Administration that the federal government should fund long-term, high risk R&D which cannot be undertaken effectively by the private sector alone. We believe that the specific projects for which we seek support qualify.

These projects are large scale and involve very sophisticated technology; thus, they require a number of years to progress from the experimental to the operational stage. Taken alone, the long-term nature of this research discourages private sector investment -- especially in a regulated industry.

Moreover, rate regulation imposes other disincentives. If a project is unsuccessful, the expenditures may be disallowed as "imprudently" made. This shifts the expense entirely to the shareholders. On the other hand, the benefits of a successful project are enjoyed only by ratepayers via reduced rates. Thus, the risk of receiving no return on R&D investment discourages devoting capital to such projects.

BENEFITS OF GAS-RELATED R&D

Natural gas serves over half of both residential and commercial establishments in the U.S. and more of American industry than any other single fuel. Competitive price, cleanliness, availability, convenience and efficiency all contribute to consumer demand, which we believe is a barometer of gas desirability.

Further, gas provides a secure source of energy because foreign developments do not disrupt our supply. Greater recovery through improved technology will improve supply security for residential customers and further assure companies of the supply stability on which long term business decisions often depend.

NEED FOR BALANCED RESEARCH

The Administration's FY 1984 budget proposals, if adopted, would devote a high proportion of funds to a fuel which, in the foreseeable future, will provide a low proportion of primary energy consumed in the U.S. That is, nuclear power consumption is quite low compared to other fuels, yet the Department of Energy budget proposal allocates over 50% of the R&D funds to this area. In contrast, fossil fuel supplies over 90% of U.S. primary energy use but receives only 6.1% of the R&D funds in the Administration's budget proposal.

In its action on the FY 1983 DOE budget, Congress corrected a similar imbalance and appropriated $311 million for fossil fuels.

RECOMMENDED GAS-RELATED RESEARCH PROJECTS

A. Coal Gasification: $50 million, minimum

The production of synthetic fuels will be a major contribution to the long term energy supply. Coal gasification, creating environmentally benign methane, can account for a major portion of this contribution. Although the U.S. is estimated to have vast coal reserves, up to 438 billion tons, only about half of these reserves can be recovered with current levels of technology. Technological improvements resulting from R&D, some of which are discussed below, will permit recovery of even more of our coal resources by expanding the breadth of coal feedstock that specific conversion methods can accept.

In-situ coal gasification could triple the nation's economically recoverable coal reserves by obtaining energy from unmineable deposits, but directional burning and long term controlled burning must be improved. However, the Administration proposes no funds for underground gasification technology development. Rather, it requests $2 million for environmental and advanced research, such as the controlled retracting injection point (CRIP) project. While these areas are important, other technology development would allow recovery of substantial coal reserves.

An active catalyst development program can yield supply benefits in two ways. First, it would provide a basis for the development of advanced coal conversion processes. Second, certain catalysts can accelerate chemical reactions within a gasifier and downstream processing systems, contributing to economical conversion processes and environmental control.

Pressurized ash agglomeration, which has been proven in large equipment with bituminous coals, could be extended to yield additional SNG from lower rank coals.

Support technologies for R&D will yield increased efficiency and production in coal gasification. Further studies and testing will improve gasification processes in the following ways: identifying contaminants in gasifier effluents; improving the understanding of the effects of high temperature and pressure on fluidization; determining the effects of contaminants in coals on the conversion process; reducing moisture and upgrading the heating value of low-rank coals such as lignites; and, adding data correlations to allow scientists and engineers to transfer empirical evidence into commercial application.

Coal gasification system component development would improve upon conventional technology, which uses process gas or steam to feed coal into high pressure gasification systems. This causes unavoidable loss of product gas, due to certain inefficiencies in compression systems. Better sealing equipment, such as a liquid sealed lockhopper system, would eliminate this loss of product gas.

Advanced gasification concepts (e.g., reductions in the size and/or number of equipment items in a conventional process) could improve conventional gasification process designs. In addition, gasification with carbon dioxide, rather than steam, offers system flexibility and more economical functioning. Full evaluation of this concept requires additional data.

Hot gas cleanup, via improved methods for removing corrosive acid-gas, could improve overall coal gasification efficiency and environmental acceptability.

Instrumentation and gasification development would permit continued research in several important areas. These include the examination of solids flow measurement and identification, improvement of devices for measuring erosion and wear (due to flow of solids) in transfer lines and metering components, and on-line análysis and metering of gases and vapor species.

B. Unconventional Natural Gas: $32 million, minimum

Gas from some of the sources discussed below can be extracted in rather small quantities using current technologies. More advanced methods of production will allow potentially vast additions to these resource bases.

Current production of gas from Devonian shales is limited to what producers can extract from around or below the shales, due to the low permeability of this type of rock. Improved techniques for "fracturing" the shale would allow gas to flow through it more readily, increasing recoverable supplies. Since only about 2-10% of this resource is producible at current levels of technology, advancements in "fracturing" may yield dramatic increases in this gas supply.

Tight sands gas is currently produced in relatively small quantities. Most of this resource base lies in lenticular formations -- long, narrow shafts reaching far down into the earth -- from which gas cannot be produced efficiently with current technology. Improved hydraulic, chemical and explosive fracturing methods would allow recovery of the 100-200 Tcf estimated to be economically feasible.

Advanced sources of unconventional natural gas, such as gas hydrates and abiogenic methane, may have tremendous supply potential if certain theories regarding their origin and extent are correct. Efforts to confirm these theories could yield an enormous supply payoff.

Large reservoirs of geopressured methane are thought to exist, especially along the Texas and Louisiana Gulf Coast. A substantial amount of these supplies (from 42 to 1200 Tcf) could be recovered with improved methods of brine disposal and development of materials capable of withstanding high pressures and corrosive elements encountered in drilling for this gas.

Methane from coal seams can be produced by hydraulic fracturing of the seam. However, high pressure combustion techniques, such as those used to link wells prior to in-situ coal gasification, may improve stimulation of methane production. Once the combustion techniques open channels in a coal seam, much higher long-term production rates are possible than if hydraulic fracturing had been used. Depending on the level of advancement in technological capabilities, among other things, recoverable gas from this source may range up to 60 Tcf.

C. Fuel Cell Technology: $20 million

By using an electro-chemical conversion process, fuel cells can save significant amounts of fuel used to generate electricity. The Administration requests no funding for gas-related phosphoric acid onsite technology development. Rather, the Administration's budget proposal would provide $3 million for electric utility R&D stack tests. A.G.A. believes that the completion of onsite technology development of phosphoric acid systems (along with other fuel cell technologies) merits R&D funding because private industry is not able to invest the capital necessary for this type of research.

Improved technology in fuel cells would also provide fuel savings incentives for installation.

D. Solar/Biomass: $20 million

Refined techniques for the conversion to methane of marine, terrestrial and waste biomass may yield enormous supply payoffs since biomass represents an inexhaustible, renewable energy source. However, to capitalize fully on this potential source of energy, conversion technologies must attain the efficiency necessary to compete with alternate sources of energy.

The gas industry has identified a number of projects that will aid the conversion of biomass to methane and, when perfected, will augment the nation's energy supply. For example, studies on the thermochemical conversion of biomass, the preparation for conversion of high-water content feedstocks, and genetic engineering will improve the efficiency of the conversion process. In addition, the establishment of biomass regional centers, for organizing and coordinating research activities, would enhance the advancement of scientific knowledge in biomass conversion.

E. Conservation: $19 million

Residential consumers can conserve gas with advanced gas prime movers, which provide both heat and air conditioning, and industry can conserve through cogeneration. However, the Administration requests no funding for these areas in its R&D budget proposal. Among other things, conservation of fuel via these methods provides an immediate benefit to consumers in the form of reduced fuel costs. Further research will result in added improvements to this equipment, making additional savings possible.

Other areas of technology development that will reduce fuel consumption include the following: increasing the amount of hydrogen that can supplement gas supplies without damaging pipelines; increasing the waste heat recoverable from certain industrial furnaces with thermochemical recuperators; and, natural gas vehicles.

Natural gas vehicles face a difficulty in their limited travel range. However, a two-phase development program can solve this problem. Near-term development of light-weight, high-pressure cylinders can facilitate expansion of fleet usage. Composite materials such as fiberglass -- steel or aluminum -- graphite, can reduce cylinder weight to approach that of a conventional gasoline tank of similar capacity. For the longer term, development of new storage technologies should be pursued. For example, solid adsorbent systems could increase fuel storage capacity per unit storage volume, while decreasing the required compressor output pressure.

F. LNG Test Facility: $5 million

A national test-site for evaluating spills of various hazardous materials could provide the information necessary to improve the safety margin of handling such materials and reduce the cost of construction of new plants.

A.G.A. has been informed that $3 million in federal funds from the FY 1983 budget are available for construction of the facility. Further, we are told that funds from the DOE operating budget are available for data correlation at the facility. We believe that a total of $5 million for both construction and data correlation will meet these needs at the facility and that, if full funding cannot be expended during FY 1983, the difference should be made up in the FY 1984 R&D budget.

It is possible that some or all of future operating and maintenance costs could be recovered through the use of user fees. This would make federal appropriations a one-time expense.

CONCLUSION

A.G.A. believes that the recommendations made herein are for long-term, high risk projects and will lead to the successful completion of current programs that would not otherwise be funded by the private sector. Congress can provide a more balanced R&D program than the Administration's budget proposal by appropriating funds in line with these recommendations.

Further, all of the funds which A.G.A. recommends will be applied to research projects that will improve current technologies to the levels required to meet the nation's future energy needs. Since gas represents a source of energy for millions of consumers, the supply benefits of gas-related R&D funding will accrue to a very wide range of our populace.

A.G.A. urges Congress to consider the energy security for our country that will result from expanded supplies of domestic gas.

Although alternative energy supplies are currently rather plentiful, we believe that the wise energy policy course to follow includes developing technology that will allow full exploitation of domestic resources, which are not subject to foreign supply disruptions.

Attached to this testimony is a list of the specific minimum funding levels recommended for particular R&D projects.

AGA
American Gas Association

RECOMMENDED FY 1984
DOE GAS RELATED R&D FUNDING PROGRAM
($ Millions)

$ 50			Coal Gasification
	$ 7		Underground Gasification (CRIP & Gulf)
	43		Surface Gasification
		$ 5	Catalyst
		2	Materials
		5	Westinghouse
		1	Pressurized Ash Agglomeration
		10	Support Technology (studies, testing & basic r&d)
		3	Component Development
		2	Great Plains (administer loan guarantee)
		3	Advanced Gasification Concepts (production & economics)
		2	Eastern Shale Gasification
		3	Entrained Bed Gasifier
		3	Hot Gas Cleanup (corrosive acid-gas removal)
		4	Instrumentation & Gasification Development
32			Unconventional Natural Gas
		$ 6	Tight Sands (flow characteristics of existing wells)
		6	Devonian Shale (Eastern mineback, gas content & flow)
		6	Advanced UNG (gas hydrates, abiogenic methane)
		12	Geopressured Methane (additional well & instrument existing)
		2	Methane from Coal Seams (new production techniques)
20			Fuel Cell Technology
		$11	Molten Carbonate (component design, test & analysis)
		6	Phosphoric Acid
		3	Advanced Concepts
20			Solar/Biomass
		$ 9	Biomass Conversion (reacter system & new processes)
		5	Genetic Engineering in Biomass Growth & Harvest
		4	Biomass Regional Centers (information dissemination)
		2	Waste Conversion Technology (two phase process)
19			Conservation
		$ 4	Advanced Gas Prime Movers
		4	Industrial Cogeneration
		3	Hydrogen (production technology)
		3	Thermochemical Recuperator (excess heat recovery)
		2	Dessicant Systems (space conditioning)
		2	Industrial Catalytic Gas Combustor
		1	Alternative Fuels Utilization (Natural Gas Vehicles)
5			Safety
		$ 5	LNG Test Facility
$146			TOTAL

AMERICAN GAS ASSOCIATION 1515 Wilson Boulevard, Arlington, Va. 22209

Senator MELCHER. Thank you, Mr. Stroh. Mr. David Webb, senior vice president, Policy and Regulatory Affairs, Gas Research Institute.

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT, POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE

Mr. WEBB. Thank you, Mr. Chairman. I am pleased to have the opportunity to appear before you today to discuss the Gas Research Institute's views and recommendations which we feel are necessary to establish a consistent, long-term, gas-related research program as an integral part of the Department of Energy's fiscal year 1984 budget.

To maintain a Federally funded long-term gas research program required to supplement the expanded near-term gas R&D program currently funded by the gas industry, GRI is recommending $146 million gas-related research budget.

Within the fossil energy program GRI and the gas industry are recommending funding at the level of $90 million, $16 million in the conservation program, and $32 million is recommended for renewable and geopressured methane resources plus $8 million for research on hydrogen and safety. These funding levels are consistent with the previous initiatives and leadership actions taken by this subcommittee and Congress to insure continued long-term research programs in the Department of Energy.

Before I summarize specific programmatic budget recommendations, I would like to discuss four factors that GRI used for evaluating the reasonableness of our recommendations regarding gas-related research. These four factors that we used were is the DOE budget request for gas-related research consistent with previous congressional action and the administration's own policy?

Two, has the gas industry responded to the Federal research program shift by funding more of its own research, especially near-term research?

Three, are there structural problems that limit the ability of the regulated gas industry to fund all of its own R&D?

And finally, is the gas industry's research funding recommendations consistent with previous actions of this committee and Congress?

We feel the request indicates that it is severely biased toward electric-related research, especially nuclear, which is not consistent with actions of this committee and Congress in the past and does not support DOE's policy.

To illustrate, Secretary of Energy Hodel in recent testimony stated, "Another belief I hold very strongly is that overreliance on any one energy source is unwise and that a balance among energy resources is needed."

The budget proposed by DOE does not support this policy. Since the gas-related research funding proposed for fiscal year 1984 in the fossil energy program is only $31.6 million, a drastic reduction from the $75 million approved by Congress just 4 months ago, the administration's proposed funding does not seem consistent with its own policy and certainly does not provide a stable funding base for long-term gas research.

In contrast to the inconsistency in the Federal policy for funding of long-term gas research, the response of the gas industry to revised R&D policy has been rapid and I feel very impressive. GRI will propose to its board of directors a 1984 budget for near-term gas research of $150 million, an increase of 50 percent in 2 years, concentrating on the near-term research to be consistent with the Administration policy.

Another factor that should be considered in determining the proper Federal role of the level of funding for long-term gas research is the institutional barriers that limit the regulated gas industry's ability to fund all of its own R&D. DOE's Energy Research Advisory Board in a report to the Deputy Secretary of Energy put these factors in proper perspective in its study titled, "Federal Energy R&D Priorities," and I quote from that study.

> A little over half our primary energy finds its way to consumers through the electric and gas utilities, and the utilities are regulated, price-controlled industries, selling their products not at free market prices but at controlled prices well below the replacement cost. The consequences are that consumers of gas and electricity have less of an incentive to conserve and therefore to undertake research on Conservation. Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as imprudent.

DOE in its fiscal year 1984 budget request recognized these structural problems for the regulated electric utilities by proposing a total electric-related research budget of approximately $1,450 million. However, they totally ignored the same institutional and structural deficiencies in their recommended funding for R&D for the regulated gas industry. They proposed a total gas-related research budget of only $45.5 million, less than half of the $96 million approved by Congress in December. This deficiency must be corrected by providing funding in the DOE budget for viable long-term gas-related research program.

I think when you look at these factors you will see that the GRI budget recommendation and the recommendation of the gas industry for DOE's gas-related program of $146 million is totally consistent with sound national energy policy. At the end of my testimony is a table which provides details on specific programmatic funding recommendations. However, Mr. Chairman, before I finish let me briefly mention three important recommendations in the areas of long-term research that require continued Federal support.

Surface coal gasification, the recommendation is for $43 million. Of particular importance is the development of advanced processes that can use the high-sulfur eastern coals. A specific example is the continuation of the Westinghouse agglomerating ash fluidized bed process which requires $6 million of DOE support in 1984. GRI provides approximately $4 million of coal funding for the continuing of this program.

Another important research area is unconventional natural gas, with funding at the level of $20 million. You may ask why should Congress appropriate increased funds for long-term gas supply research in fiscal year 1984? I think this is best illustrated by the administration's own fiscal year 1984 budget request where they stated:

There appears to be adequate U.S. reserves of natural gas for several decades if conventional and unconventional gas resources can be exploited. Unconventional gas will not realize its potential unless there is additional development of the scientific and engineering knowledge for associated extraction technologies.

Long-term gas supply R&D is needed now because there is a 10-year leadtime from the beginning of research to when you actually achieve production. DOE should focus its research on the lenticular sands and continue the multiwell experiments at a funding level in 1984 of $6 million.

In the Devonian shales located throughout the East, their program should address research primarily on the Eastern Mineback program at a funding level again of $6 million.

Finally, Mr. Chairman, one other area I would like to briefly mention is the onsite fuel cell program, with the gas industry recommending appropriations and funding of $20 million.

The gas industry and GRI have made a major increase in funding in the last 2 years for phosphoric acid fuel cell systems to pick up near-term research that has been dropped by DOE. The GRI budget has increased from $11 million in 1982 to over $19 million in 1983 to pick up this near-term research. This total assumption by industry of funding for near-term research is consistent with the national policy.

However, the continued funding of the required long-term technology development program is a combination responsibility of industry and DOE. DOE has initiated a 4-year program for this research with the manufacturer United Technologies Corp., that requires $6 million in fiscal year 1984. The gas industry has a parallel program of approximately $12 million to fund this work.

In summary, a viable Federal program consistent with administration energy policy requires a budget in fiscal year 1984 for long-term gas research of $146 million. It should be noted that this recommendation is essentially the same level of funds appropriated by Congress for gas-related research in fiscal year 1982 and is consistent with the actions taken by this committee and Congress just 4 months ago in approving the fiscal year 1983 funding level.

Mr. Chairman, that completes my testimony. I will be glad to answer any questions you might have.

[The prepared statement of Mr. Webb follows:]

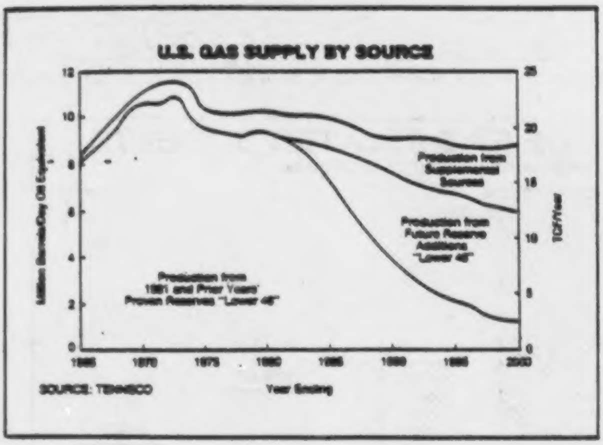
Statement of David O. Webb, Senior Vice President
Policy and Regulatory Affairs, Gas Research Institute
Before the Subcommittee on Energy Research and Development
Senate Energy and Natural Resources Committee
May 3, 1983

Mr. Chairman and Members of the Committee:

The Gas Research Institute (GRI) is an independent, not-for-profit scientific research organization created by the gas industry in 1976 to plan, finance, and manage an expanded and fully coordinated gas-related research and development (R&D) program for the mutual benefit of the regulated gas industry and its ratepayers. In compliance with stipulated procedures, GRI submits its annual plan and five-year R&D progam to the Federal Energy Regulatory Commission (FERC) for review and approval as part of a public proceeding.

I am pleased to have the opportunity to appear before you today to discuss the gas industry's views and recommendations considered essential for establishing a consistent long-term gas-related research program as an integral part of the Department of Energy's (DOE) FY 1984 budget.

The need for a consistent federal policy and adequate funding for long-term gas research is evident when you examine where the nation's energy supplies will be derived over the next 20 years. There is wide agreement between both private and federal forecasts that the U.S. will continue to rely on oil and gas for over 70 percent of its energy needs in the year 2000. While the U.S. has a short-term gas supply surplus now, more and more of the required gas supplies must come from supplemental sources as we approach the year 2000.

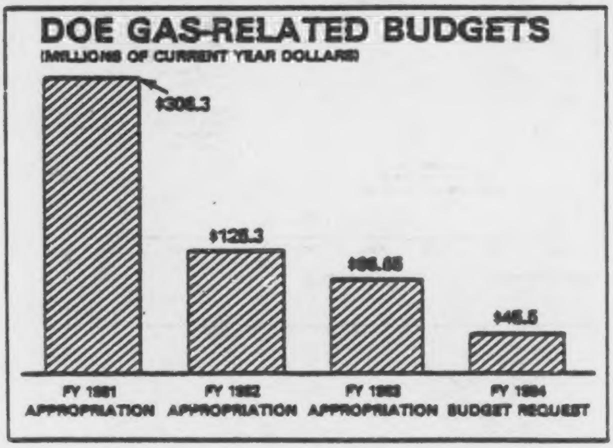

U.S. GAS SUPPLY BY SOURCE

SOURCE: TENNECO

Establishing the technology base to develop these supplemental supplies at cost-competitive prices requires a lead-time of 6 to 15 years, depending on the resource. In other words, we must start now. If we don't take the steps necessary to develop the technology base required to use these domestic resources efficiently, the level of oil imports will rise rapidly, again increasing our dependence on insecure oil from politically unstable regions. The current softening of world oil prices provides us the opportunity to pursue this critical technology development in an orderly fashion rather than on a crash basis. To severely reduce federal funding for the long-term R&D required to develop these new gas technologies at this time in an attempt to solve short-term fiscal problems only restricts the development of critically needed new technologies and provides little if any assistance to the goal of reducing federal deficits.

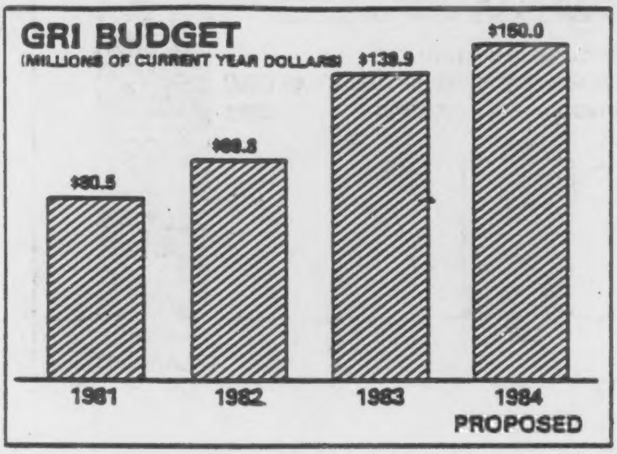
Now that we have the time, we must seize this opportunity to establish and develop the required long-term non-nuclear R&D technology base by funding within DOE a total Fossil Energy Research Program for FY 1984 of approximately $310 million and a total Conservation R&D Progam of approximately $100 million, essentially the same funding level as appropriated by Congress for FY 1983. To maintain a minimum federally funded long-term gas research program required to supplement the expanded near-term gas R&D program currently funded by the gas industry, GRI is recommending a $146 million gas-related research budget. Within the Fossil Energy Program, GRI and the gas industry recommend funding for gas research at a level of $90 million. A gas research program of $16 million is recommended in the DOE Conservation budget and a $32 million budget is recommended for renewables and geopressured methane plus $8 million for hydrogen and safety. These funding levels are consistent with previous actions of this committee and Congress and will continue critical long-term research programs.

To illustrate the importance of providing a balanced and adquate federal gas research program, Secretary of Energy Hodel in recent testimony on the DOE budget stated, "I believe that energy has an importance far beyond most commodities because directly and indirectly energy is significant to every aspect of the U.S. economy . . . Another belief I hold very strongly is that overreliance on any one energy source is unwise and that a balance among energy resources is needed." GRI agrees with these positions. However, to implement this policy, DOE must continue to provide a stable funding base for long-term, high-risk gas-related research while industry is increasing its funding of near-term research. The budget proposed by DOE does not support this policy. The gas-related research funding proposed for FY 1984 in the Fossil Energy Program is only $31.6 million, a drastic reduction from the $75 million approved by Congress just four months ago. The Administration's proposal does not seem consistent with its own policy and certainly does not provide a stable funding base for long-term gas research.

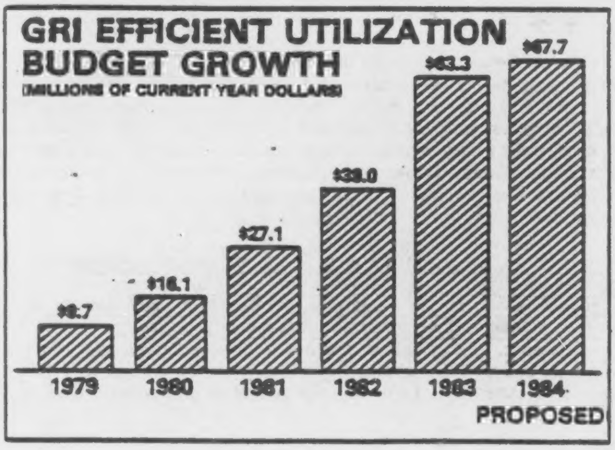


GAS INDUSTRY FUNDING OF R&D

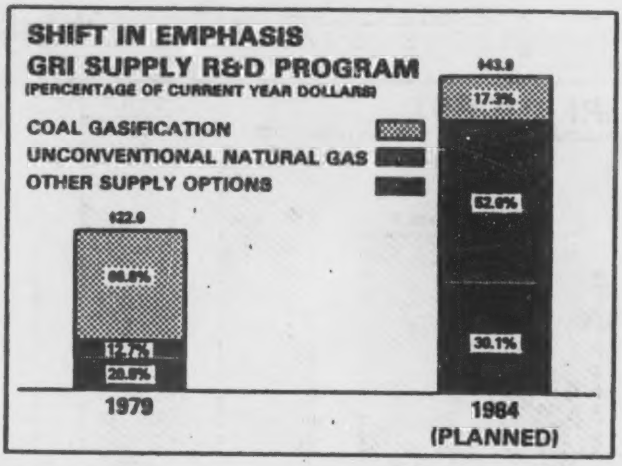
In contrast to the inconsistency in the federal policy for and funding of long-term gas research, the response of the gas industry to the revised government R&D policy has been rapid and very impressive. GRI will propose to its Board of Directors a 1984 budget of $150 million, an increase of 50 percent in two years, mostly for near-term research.



In response to federal energy policy and since it promises the most potential for ratepayer benefits in the near term, GRI's funding for research in efficient utilization continues to receive the largest budget increase from a level of $38.9 million in 1982 to a proposed level of $67.7 million in 1984 or approximately 54 percent of the total R&D budget.



Funding for the supply research program grows from a 1979 level of $22.0 million to a proposed level in 1984 of $43.9 million with the increase concentrated in near-term unconventional gas R&D.



GRI's emphasis on near-term research has significantly contributed to increased levels of coordinated funding from private industry. Industrial coordinated funding has increased from $8.8 million in 1979 to an expected $30 million in 1982. However, GRI's experience with industry cofunding has indicated industry's unwillingness to cosponsor research unless the payback potential is within five to eight years. The majority of coordinated funds are in areas that will be commercial in three to five years. Therefore, to provide a stable base of funding for long-term gas research DOE should fund approximately $146 million in the FY 1984 budget.

GAS TECHNOLOGY BASE

Another factor that should be considered in determining the proper federal role and the level of funding for long-term gas research is the institutional barriers that limit the regulated gas industry's ability to fund R&D. The gas technology base to develop cost-competitive supplemental sources of gas and more energy-efficient processes and end-use equipment required to compete with alternative energy sources is not established and in place. DOE's Energy Research Advisory Board (ERAB) in a report to the Deputy Secretary of Energy put these factors in proper perspective in its study Federal Energy R&D Priorities. I quote:

> A little over half our primary energy finds its way to consumers through the electric and gas utilities, and the utilities are regulated, price-controlled industries, selling their products not at free market prices, but at controlled prices well below replacement cost. (Emphasis added). The consequences are that consumers of gas and electricity have less of an incentive to conserve (and, therefore, to undertake research on conservation). . .

> Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as "imprudent." (Emphasis added). In the case of electricity (but not gas) a substantial amount of R&D has been undertaken by large research-oriented equipment suppliers.

DOE in its FY 1984 budget request recognized this structural problem for the electric utilities by proposing a total electric-related research budget of approximately $1,450 million. However, they totally ignored these same institutional and structural deficiencies in funding R&D for the regulated gas industry. The total proposed gas-related research budget in DOE is only $45.5 million, less than half the $96 million approved by Congress in December. While there are significant differences in the cost of electric vs. gas R&D, a ratio of over 30 to 1 is absurd. This deficiency must be corrected by providing funding in the DOE budget for a viable long-term gas-related research program.

DOE FY 1984 RESEARCH BUDGET
($ MILLIONS)

RESEARCH AND DEVELOPMENT	ELECTRIC-RELATED*	GAS-RELATED
1. CONSERVATION	$ 38.40	$ 4.20
2. FOSSIL ENERGY	44.95	31.60
3. SOLAR AND OTHER RENEWABLES	54.90	9.70
4. MAGNETIC FUSION	467.00	—
5. NUCLEAR FISSION	846.00	—
TOTAL R&D	$1451.25	$45.50

*THIS IS A VERY CONSERVATIVE ESTIMATE OF THE REQUEST FOR ELECTRIC-RELATED RESEARCH AND DEVELOPMENT. NO PORTION OF THE [illegible] MILLION REQUESTED FOR GENERAL SCIENCE IS INCLUDED EVEN THOUGH MOST OF THE ENERGY-RELATED BENEFITS COMING FROM THIS RESEARCH WILL BENEFIT THE ELECTRIC UTILITY INDUSTRY. ALTHOUGH MOST OF THE ENVIRONMENTAL AND HEALTH RESEARCH AND DEVELOPMENT FUNDS ARE SPENT ON R&D RELATED TO NUCLEAR POWER, NONE OF THE [illegible] MILLION BUDGET REQUEST IS INCLUDED.

RECOMMENDED GAS-RELATED RESEARCH PROGRAM

Without adequate continued federal funding for the long-term R&D needed to establish a sound gas technology base, supplemental sources of gas and more efficient processes will not become available at competitive prices within the time required to prevent permanent market loss to imported oil. Discussed below are five important long-term areas of gas supply research that are consistent with the Administration's policy guidelines and require continued federal sponsorship and funding.

Gas Supply Research

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
SURFACE COAL GASIFICATION	$53.1 million	$39 million	$43 million

One of the most promising, abundant long-term gas supply resources is the conversion of coal to gas. Of particular importance is the development of advanced processes that can use high-sulfur Eastern coals. For several years GRI and the Department of Energy jointly supported the initial development of several advanced gasification processes. In 1981, test results and technical and economic evaluations justified our concentrating on the further development of the Westinghouse agglomerating ash, fluidized bed process. Continued federal support in FY 1984 of $6 million is needed for this technology development. Funds will be used to continue the process development unit (PDU) tests, cold-flow test facility (CFTF), and laboratory research with a major emphasis on environmental aspects. GRI and industry will provide approximately $4 million of cofunding.

In addition, federal support is needed to continue basic research programs in improved catalysts, materials, components, and instrumentation since significant improvements in the economies of coal gasification can result from improvements in downsteam processing systems which currently comprise about one-third of the installed plant investment. A viable DOE program at levels consistent with the past two years' appropriations is necessary to continue the timely development of advanced coal conversion processes.

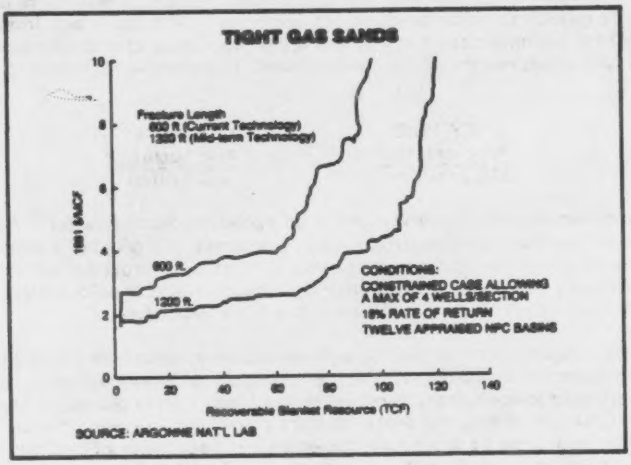
	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
UNDERGROUND COAL GASIFICATION	$8.3 million	$6 million	$7 million

Underground coal gasification offers the largest potential for major reductions in capital investment for production of medium-Btu gas or synthesis gas from coal, but the high risks associated with the requisite oxygen-blown underground gasification technology currently precludes industry from developing the technology on its own. Research on underground gasification must be continued by DOE to develop technologies capable of recovering unmineable coal reserves with both flat and steeply dipping geometries. Among the work completed under the DOE/GRI Insitu Participation Agreement was the large block tests at Centralia, Washington, in which the promising controlled retracting injection point (CRIP) technology was initially tested. GRI recommends continued development of this technology in a large field test as well as basic laboratory support of insitu gasification technology. Initial investigations in testing the Eastern coals should start.

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
UNCONVENTIONAL NATURAL GAS	$8.7 million	$13.9 million	$20 million

With the U.S. confronted with unsatisfactorily high deficits and the gas industry facing a demand- rather than supply-constrained market, why should the Congress appropriate increased funds for long-term gas supply research in FY 1984? The reason is the lack of the required technology base. As the Administration states in the FY 1984 budget request: "There appears to be adequate U.S. reserves of natural gas for several decades if conventional and unconventional gas resources can be exploited. Unconventional gas will not realize its potential unless there is additional development of the scientific and engineering knowledge for associated extraction technologies." (Emphasis added). Long-term gas supply R&D is needed now because there is a ten-year lead-time from the beginning of research to the production of significant cost-competitive additional supplies.

The National Petroleum Council's (NPC) estimate of an additional 200 Tcf of reserves through development of advanced technology for tight lenticular formations and Devonian shales illustrates the potential and rationale for the high priority of this research. GRI is increasing its research budget for near-term work in these areas from $10.8 million in 1982 to a proposed $23.1 million in 1984. Since industry's focus in tight formations has been in blanket sands, DOE should focus on lenticular sands with a wide range of long-term technology issues. This is best accomplished through the continuation of the Multi-well Experiment at an FY 1984 funding level of $6 million. Continued support is needed in identification of continuity of lenses, long-term production testing, and down hole fracture diagnostics instrumentation. As an example of what can be accomplished by increasing the technology base, in a study done by Argonne National Laboratory for GRI, it was found that with current technology, projected tight sands recovery is approximately 65 Tcf at a price of just under $4/Mcf. If research can develop the technology to meet a mid-term R&D goal of doubling the fracture length, nearly 110 Tcf will become available at the same price.



SOURCE: ARGONNE NAT'L LAB

In Devonian shales the DOE program should address long-term, high-risk research at a funding level of $6 million. Priority should be given to establishing an Eastern Mineback Program consisting of a combined surface/underground test facility designed to substantiate the methodology and results of stimulation technology through a series of experiments. Researchers will have the capability to make actual physical measurements and detailed observations of the shale in place to determine the effect of stimulation, the behavior and extent of fracture, and the accuracy of diagnostic tools, among other factors.

Because of the long-term, high-risk but very high-payoff potential from generic exploration of methane hydrates, a proper federal role should include research on physical properties of hydrates, hydrate recovery, gas production from hydrates, and the determination of the hydrate resources base. This will require $3 million to $4 million in FY 1984.

Additional federal support of $2 million is needed for the formulation of critical tests on the abiogenic hypothesis and to take a broad look at all aspects and consequences of the abiogenic gas hypothesis.

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
GEOPRESSURED RESOURCES	$17.3 million	$8.4 million	$12.0 million

While GRI's research efforts in this area have focused on near-term recovery of free gas trapped in reservoirs, the DOE program has focused primarily on the long-range recovery of methane dissolved in brine. Recently, an industry committee assessed the DOE program in view of the budget cuts and recommended that DOE complete the testing of the design well projects. No new well tests are recommended until the current projects are completed and additional funding is provided. GRI supports these recommendations and proposes that a logical next step is to broaden the program to include a design well test in a hydropressured aquifer which may or may not include free gas. This test would provide information on gas liberation and transport, reservior and fluids properties, and artificial lift requirements to produce gas and brine. DOE has a legitimate and important role in R&D for enhanced recovery of gas from geopressured and hydropressured aquifers due to the long-term nature of the research and its potential high payoff.

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
BIOMASS	$20.5 million	$16 million	$20 million

The unique advantages of biomass make it an excellent candidate for many regions of the United States that lack conventional energy resources. To provide a model for developing biomass energy programs on a regional basis, GRI began a program with the University of Florida's Institute of Food and Agricultural Sciences. DOE should expand the regional biomass concept by providing $4 million in the FY 1984 budget.

GRI is conducting research on plants, such as seaweed, which grow rapidly in the ocean and can be converted to methane. Marine farms, once developed, would not compete with valuable land space needed for food production. GRI is currently involved with projects at Catalina Island, the Santa Barbara coast, and in New York using kelp indigenous to each area to determine the economic feasibility of this concept and the kelp growth rates and subsequent methane yields. Federal funds of $2 million should be directed at basic research on increasing kelp yield through selective genetic engineering.

Federal support is needed in biomass conversion, growth, and harvesting. It is recommended that $5 million be committed to conversion technologies to include work with grasses and herbaceous feedstocks on a regional basis to allow resource assessment of the use of these crops for methane production, to investigate environmental effects of the removal or utilization of agricultural residues from fields, and to continue macroalgal growth studies without being confined to land-based systems.

Efficient Utilization Research

DOE has a continuing role in funding long-term research in the more efficient use of gas. Fuel cells and industrial processes offer great promise for significant improvements.

FUEL CELLS	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
Onsite	$ 5.6 million	$ 4.0 million	$ 6 million
Molten Carbonate	9.6 million	7.5 million	11 million
Advanced Concepts	4.2 million	5.0 million	3 million
	$19.4 million	$16.5 million	$20 million

The gas industry and GRI have made a major increase in funding for onsite phosphoric acid fuel cell systems in 1983 (from $11.3 million in 1982 to $19.6 million in 1983) to offset the loss of DOE funds for near-term research. These funds will be used to continue the manufacturing and field testing of 48 units under the joint program with DOE. This total assumption by industry of funding for the field tests in 1983 and 1984 is consistent with national policy. However, the continued funding of the required long-term technology development program to increase the reliability and lower the costs of these onsite systems must be a combined DOE and gas industry responsibility. DOE has initiated a four-year program for this research with the manufacturer United Technologies Corporation (UTC) that requires $6 million in FY 1984. The DOE work concentrates on the fuel cell stack; the fuel processing system, including catalyst research; the inverter; and specialty heat exchangers. GRI has a parallel $12 million technology development program with UTC concentrating on component technology, component fabrication techniques, and system design. Together, these two research programs provide funding for the technology base required for the fuel cell to be developed.

Also, continued DOE long-term research is needed on advanced fuel cell concepts such as molten carbonate ($11 million) and solid oxides ($3 million). These systems, which could be field tested in the early 1990s, have the potential to be more efficient and to lower overall costs of energy. It is important that the government continue this long-term fuel cell research while the gas industry assumes funding for the near-term research and field testing of prototype onsite units.

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
INDUSTRIAL CONSERVATION	$10.5 million	$12.7 million (4.0 million)*	$16 million

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*Represents specific gas-related projects.

There is a continuing need for federal funding of basic technology development in the more efficient utilization of gas in the industrial sector. As ERAB has reported, the manufacturing sector is so diverse that individual companies cannot capture the benefits of the R&D; therefore, the federal research role becomes critical. Specific technology-based research is needed on an advanced gas prime mover ($4 million), and industrial cogeneration ($4 million).

The problems associated with developing a small, economic and highly reliable gas prime mover for residential and commercial applications (heat pumps, cogeneration, refrigeration, and water heating) are numerous and difficult to solve. Funding and research will be required to meet stringent performance, life, and reliability requirements of the residential and commercial sectors. Major research needs include: dynamic component matching, improved high-temperature materials, ceramic development and application, better seal technologies, improved heat exchangers, better use of electronic engine controls, and high-temperature lubricants. A long-term federal research program to develop a small gas engine (prime mover) at a funding level of $4 million a year is needed.

Continued federal support is also needed for the development of improved combustion efficiency of industrial furnaces and boilers. Specifically, support is needed to develop an industrial catalytic surface combustor which would improve heat transfer rates and efficiency and reduce the combustor size. This would ultimately lead to substantial reductions in capital and operating costs.

Research support is needed for desiccant systems which are an attractive alternative to conventional air conditioning systems offering a potential fuel savings of 20 percent. The use of gas-fired desiccant systems for air drying shows good promise for meeting the needs for dehumidification in tight, well-insulated structures.

Safety

	FY 1982 Appropriation	FY 1983 Appropriation	FY 1984 Gas Industry Recommendation
LNG SAFETY	$6.3 million	$3.0 million*	$5 million

*It is unclear if funding to establish the Nevada test site facility is included in the FY 1983 Continuing Resolution. If, in fact, funding is committtted in FY 1983 to establish the test site, only the $1.5 million is needed for the initial start-up activities in 1984.

GRI has been concerned with DOE's plan to terminate its LNG research program and close the test site at China Lake, California, where LNG spill testing has been conducted. GRI recommends the government establish a national test site in Nevada where large quantities of LNG or any hazardous gaseous material could be released and tested. It is estimated that $3.5 million is needed to establish the site and $1.5 million is needed for manpower and administrative costs. This is a one-time expenditure since future costs with the exception of $750,000 a year for manpower would be covered through user fees. Industry strongly supports establishment of this facility and the user fee concept for future operation.

SUMMARY AND RECOMMENDATIONS

A viable federal program consistent with Administration energy policy requires a budget in FY 1984 for a long-term gas research program of approximately $146 million. (See Table 1). It should be noted that this recommendation is consistent with the level of funds appropriated by Congress for gas-related research in FY 1982 and is approximately the same as appropriated by this committee and Congress just four months ago for the FY 1983 funding level. (See Table 2).

Table 1

RECOMMENDED FY 1984
DOE GAS-RELATED RESEARCH
($ MILLIONS)

COAL GASIFICATION ADVANCED CONCEPTS, UNDERGROUND GASIFICATION, SHALE, CATALYSTS, MATERIALS, INSTRUMENTATION, FLUIDIZED AND ENTRAINED BED, SUPPORT TECHNOLOGY, COMPONENTS	$50
UNCONVENTIONAL AND GEOPRESSURED RESOURCES TIGHT SANDS (LENTICULAR), DEVONIAN SHALE, COAL SEAM METHANE, GEOPRESSURED, ABIOGENIC, HYDRATES	32
BIOMASS DIGESTOR/CONVERSION, GROWTH, REGIONAL, WASTE	20
FUEL CELLS ONSITE PHOSPHORIC ACID, MOLTEN CARBONATE, ADVANCED CONCEPTS	20
CONSERVATION ADVANCED GAS PRIME MOVER, INDUSTRIAL COGENERATION, DESSICANT SYSTEMS, THERMOCHEMICAL RECUPERATOR, INDUSTRIAL CATALYTIC APPLICATIONS, ALTERNATIVE VEHICLE CONCEPTS	16
HYDROGEN	3
LNG SAFETY	5
	$146

Table 2

DOE GAS-RELATED BUDGET
($ MILLIONS)

	FY 1981	FY 1982	FY 1983	FY 1984 BUDGET REQUEST
FOSSIL ENERGY				
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT	$ 14.5	$ 12.5	$ 7.35	$ 1.0**
ENHANCED GAS RECOVERY	30.6	8.7	13.9	5.2
ONSITE FUEL CELLS R&D	9.5	5.6	14.0*	6.5**
SURFACE COAL GASIFICATION	164.9	53.1	39.0	16.9
UNDERGROUND COAL GASIFICATION	10.0	8.3	6.0	2.0
GEOPRESSURED METHANE	35.8	17.3	8.4	0.0
ENERGY CONSERVATION	22.0	10.5	4.0	4.2
BIOMASS	12.5	3.0	4.0	9.7
LNG SAFETY	6.5	6.3	*	0.0
TOTAL	$306.3	$125.3	$96.65	$45.5

*TEN MILLION DOLLARS OF THE FUEL CELL FUNDING IS FOR RESEARCH ON MOLTEN CARBONATE AND SOLID OXIDE FUEL CELL TECHNOLOGY. FUNDING FOR LNG SAFETY IS UNCERTAIN ALTHOUGH IT APPEARS THAT $3.9 MILLION WAS APPROPRIATED.

**NO FUNDING IS REQUESTED FOR ONSITE PHOSPHORIC ACID TECHNOLOGY DEVELOPMENT. THE FUNDING SHOWN IS FOR MOLTEN CARBONATE AND SOLID OXIDE FUEL CELL RESEARCH. MOST FY 1984 FUNDING FOR ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT IS SHOWN AS PART OF THE COAL GASIFICATION BUDGET TO COMPENSATE FOR THE COAL GASIFICATION FUNDS BEING USED IN SUPPORT OF LIQUEFACTION APPLICATIONS.

Senator **Melcher**. Let's start with the $150 million that GRI proposed to the board of directors.

Mr. **Webb**. Yes, sir.

Senator **Melcher**. I can read through this testimony and get the impact of that.

Where is that $150 million going to come from?

Mr. **Webb**. All right, sir. You mean how the $150 million will be distributed in our own program?

Senator **Melcher**. No; where it is going to come from.

Mr. **Webb**. The Gas Research Institute is a not for profit research institute formed by the gas industry, and it is a voluntary membership of the gas industry. We have over 200 members, and it comes from contributions from the members. We file an annual plan with the Federal Energy Regulatory Commission which is reviewed and approved by the Federal Energy Regulatory Commission and the 50 State commissions, and then that plan is either approved or modified or approved as modified, so the funding comes through the sale of gas that is transported in the interstate commerce.

Senator **Melcher**. What you are saying is that you think that a certain number of consumers who are buying gas for a certain number of companies which are part of the organization are going to pay for that $150 million? Is that what you are going to suggest, they will pay $150 million for research in 1984?

Mr. **Webb**. Yes, sir, primarily for the near-term research that the DOE has dropped.

Senator **Melcher**. All right. What you are recommending is that there be at least $146 million of Federal funds for long-term research?

Mr. **Webb**. Yes, sir.

Senator **Melcher**. That is a fair number, and also when you mentioned how much you put into coal you didn't separate how much is put in for utility companies. You mentioned $1.4 billion in the budget.

Mr. **Webb**. Yes, sir. That is just the Federal Government's.

Senator **Melcher**. For electric utilities?

Mr. **Webb**. Yes, sir.

Senator **Melcher**. It is primarily nuclear?

Mr. **Webb**. Yes, sir.

Senator **Melcher**. Precious little of that goes for anything but nuclear.

Mr. **Webb**. That is absolutely correct.

Senator **Melcher**. Thank you. There is definitely imbalance on both sides. I mean consumers who buy the gas from those 200—did you say 200 companies?

Mr. **Webb**. Yes, sir, 200 members.

Senator **Melcher**. Can come up with $150 million for the long-term benefit of everybody, so the Federal Government can come up with $146 million for long-term research; thank you, Mr. Webb.

Dr. Lee.

STATEMENT OF DR. BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY

Dr. **Lee**. Thank you, Mr. Chairman. I am Bernard Lee, president of the Institute of Gas Technology, a not-for-profit energy organization R&D organization in Chicago. I am privileged to appear before you as a technologist who has been performing R&D in the fossil energy field all my career, and I would like to ask that my full testimony be included in the record.

Senator **Melcher**. It will be made a part of the record.

Dr. **Lee**. Thank you. We feel the goal of our long-term energy policy should be to make our Nation invulnerable to the loss of energy imports. Despite OPEC's appearance of a breaking alliance at the moment, the cartel will stay and will grow strong again as soon as the world economy recovers. This is no time for slackening our efforts to develop the energy technology that is needed for a stable future.

We must continue to stress efforts to develop indigenous resources and to use our energy more efficiently. To solve long-range energy problems, continuity in support is critical. The private sector could not and should not shoulder the major responsibility for planning and funding R&D in areas of national concern, and energy is most certainly a national concern. However, the fiscal year 1984 nondefense energy R&D budget is substantially reduced. In particular, the nondefense, nonnuclear energy R&D budget is less than half of the fiscal year 1984 level which was already minimal. Especially glaring is the overwhelming emphasis on nuclear R&D at the expense of nonnuclear. This imbalance is totally out of step with the realities of the foreseeable future in which most of our Nation's energy supply will have to come from non-nuclear sources.

As a technologist, I am very concerned about the R&D and commercialization of new technology. The fiscal year 1983 budget directives stress support for research up to and including process development unit scale which itself fell short of bridging the gap to commercial acceptance. Now the fiscal year 1984 budget directives further widen the gap to commercialization by instructing no funding of research past proof of concept at the bench scale. As a result of omitting such critical links in technology development, the Government will not receive adequate return on its investment in energy R&D of previous years.

In fiscal year 1984 to restore some balance between nuclear and nonnuclear R&D programs, I support the gas industry's recommendation for $146 million in DOE appropriations for gas-related R&D in the major categories as enumerated—$50 million for gasification; $32 million for nonconventional and geopressured gas; $20 million for biomass; $20 million for fuel cells; $19 million for conservation; and $5 million for LNG safety; in addition to the $146 million, $4 million is recommendation for R&D in thermal energy storage.

There are a few specific programs that IGT is recommending for consideration—$8 million in coal gasification supporting research to learn more about coal ash constituents, to obtain fluidization data, to improve feedstock characteristics, and to transfer R&D results to the technical community; $2 million to develop an existing facility for the CFFR process for extracting energy from oil shale fines which are now discarded; $2 million to complete the test program on thermochemical conversion of biomass to synthesis gas using an existing pressurized fluidized bed system built with DOE funds; $4 million to use existing facilities to enhance the technology base of carbonated fuel cell through the evaluation of components, testing prototype endurance, measuring the effect of contaminants, and electrolytes preparation.

In the area of industrial conservation, there are two promising approaches—one for $3 million to develop thermochemical recuperation of high temperature waste heat, and the other for $2 million to develop an advanced combustor prototype; finally, in the energy storage area, $4 million for further development of thermal energy storage using composite molten salt phase-change materials.

That completes my testimony, and I thank you for giving me this opportunity to present my views.

[The prepared statement of Dr. Lee follows:]

Statement by Bernard S. Lee, President
Institute of Gas Technology
Before the Senate Committee on Natural Resources
Subcommittee on Energy Research and Development
Oversight Hearing on the
President's Proposed FY1984 Energy Research and Development Programs

May 3, 1983

Mr. Chairman and Members of the Subcommittee:

My name is Bernard S. Lee. I am president of the Institute of Gas Technology, a not-for-profit, energy R&D organization in Chicago.

I would like to make some observations of our national attitude toward energy R&D, and, in particular, toward striving for excellence and leadership in energy technology and then maintaining that position. I am deeply disturbed by the absence of a consistent and sustained national policy for energy R&D. This absence causes regular, predictable, and highly disruptive and wasteful oscillations in our technology development effort.

No one asks why we should be preeminent in national defense, because we would never think of importing major portions of our defense technology. Our national commitment to public health and agriculture through well funded and sustained efforts have brought us the best health care system and the most productive agricultural industry in the world. Even though both industries are well established, we continue, as we should, to fully support them at the federal level in order to maintain our position of leadership.

But we seem to be unwilling to strive for a similar leadership position in energy technology. Long-term energy policy should be directed toward controlling energy imports at a level at which the loss of such imports will have a minimal impact on the American economy and our national security. Despite the current OPEC disagreements about pricing and production quotas, the oil cartel will remain and will grow strong again as soon as the world economy recovers. This is no time to slacken our efforts to develop the energy technologies needed for a stable future. The only way to do this is to adopt a national energy policy which stresses the use of indigenous resources, conservation, and more efficient use of energy. To effectively carry out such a policy necessitates making a long-term commitment to energy R&D on a scale large enough to meet the goals.

To make any appreciable progress in solving long-term energy problems, continuity in government support for energy R&D is critical. Our nation has already paid a costly and unnecessary penalty when, as a result of the lack of continuity in Federal energy R&D programs, IGT and other energy R&D organizations were forced to disperse the teams of highly competent scientific and engineering specialists that took years to assemble and train. When the need arises in the future to again develop such teams, as it most certainly will, more years will be lost before the new teams become effective. The discontinuity of Federal energy R&D support is one of the major roadblocks in achieving American preeminence in energy technology.

Energy is an area of national concern. The private sector could not, and should not, shoulder the major responsibility for planning and funding R&D in areas of national concern. The federal R&D budget for FY'84 shows steady support for public health and agriculture, and a huge increase for defense. Non-defense energy R&D is substantially reduced, and, in particular, the non-defense, non-nuclear energy R&D budget is less than half of the FY'83 level, which itself was already minimal. Especially glaring is the overwhelming emphasis on nuclear R&D at the expense of non-nuclear. This imbalance is totally out-of-step with the realities of the foreseeable future in which most of our nation's energy supply will have to come from non-nuclear sources.

I am greatly concerned about current government policy regarding research and development and commercialization of new technologies. The FY'83 budget directives stress support for research up to and including process development unit scale, which itself fell short of the desirable goal of providing sufficient data for commercial development of processes by industry. Now the FY'84 budget directives further widen the gap to commercialization by instructing no funding of research activities past proof-of-concept at the bench scale. As a result of omitting such critical links in technology development, the government will be unable to receive an adequate return on its investment in energy R&D of previous years. Federal support must be continuous at a sustained level through the necessary stages of proof-of-concept, process development unit, pilot scale, and demonstration.

The private sector is unlikely to continue the development of a broad array of energy technologies once federal support is interrupted because the private sector can only concentrate on the short term in view of the arbitrary and politicized nature of the world energy arena. The private sector cannot risk its resources to strive for long-term stability when faced with the uncertainties and fluctuations of a world market controlled by different national governments. The only effective and feasible route to long-term U.S. energy stability is for the public and private sector to work together on a sustained basis. Positive results through sustained federal support are not only evident in public health, agriculture, and aerospace, but also in the energy field — the nuclear industry, solar and photovoltaics, and advanced fossil fuel conversion and utilization techniques. We must recognize that it is in our national interest to adopt a balanced and sustained policy for energy technology development.

For FY'84, to restore some balance between nuclear and non-nuclear R&D programs, I support the gas industry recommendation for $146 million in DOE appropriations for gas-related R&D. In addition, $4 million is recommended for R&D in thermal energy storage. Specific recommendations for programs are summarized in Attachment 1 and detailed in Attachment 2 of this testimony. I will highlight a few areas below.

Gasification

Of the $50 million gasification program recommended by the gas industry, in coal gasification the emphasis should be on supporting research that develops technology and assembles data that have broad applications. For this, $8 million is recommended to obtain data for the behavior of coal ash and coal constituents during gasification, to obtain process data on fluidization and gas cleanup, to improve feedstock characteristics, and to transfer R&D results to the technical community. A $1 million program is recommended to extend the ash agglomeration technique to higher pressures and to lower-rank coals using an existing process research unit capable of operation up to 500 psi.

In all current oil-shale processes, the fine particles produced during mining and feed preparation are discarded as a waste product. IGT recommends $2 million for the development of countercurrent free-fall retorting (CFFR) of shale fines using an existing bench-scale facility. This process is applicable to eastern and western shales, and has the potential for improved energy efficiency, resource recovery and environmental compatibility.

Unconventional and Geopressured Resources

This $32 million program encompasses research in tight sands, Devonian shale, geopressured methane, deep-source methane, gas hydrates, and methane from coal seams. All these areas require much research and development before these tremendous energy resources can be tapped efficiently and economically. In particular, we highlight a new approach for enhancing the recovery of methane from coal seams which is theoretically more effective than hydraulic fracturing to stimulate gas flow. A $1 million program is recommended to initiate work to stimulate gas flow by relieving built-in stresses in coal seams via controlled and limited combustion to remove very small amounts of coal.

Using a unique Computer Operated Rock Analysis Laboratory (CORAL), the properties of cores from the first two tight sands wells of the multi-well experiment in Colorado were found to be different than anticipated. For FY'84 we support a $6 million effort which would include the continued use of CORAL in a comprehensive program of core analysis, hydraulic fracturing and production testing of the wells already drilled, along with the determination of gas entrapment and production mechanisms.

We support $12 million funding for continuing production and testing of the existing four geopressured wells through FY'84. Further, we recommend DOE participate in a new well to test brine production for recovery of gas left in place after abandonment of water-drive gas reservoirs.

Biomass

The $20 million biomass program recommended by the gas industry includes research and development in the thermochemical and biological conversion of biomass, the conversion of waste, the growth and harvest of biomass and the establishment of several biomass regional centers. We highlight a $2 million recommendation to complete a RENUGAS test program for thermochemical conversion of biomass in an existing pressurized fluidized bed reactor system. On the biological conversion side, we highlight a $1 million recommendation to thoroughly study the first known inoculum which can gasify woody biomass without pretreatment.

Fuel Cells

The $20 million fuel cell program recommended by the gas industry includes support for first-generation phosphoric acid fuel cell, second-generation molten carbonate fuel cell, and other advanced concepts. In particular, the molten carbonate fuel cell system has potentially the best combination of performance, efficiency, and cost to capture a significant portion of several end-use applications. A multi-year program with FY84 funding of $4 million is recommended to enhance the technology base which focuses on using existing facilities for evaluating components, testing prototype endurance, measuring effect of contaminants, and preparing electrolytes in a controlled environment.

Conservation

The $19 million conservation program recommended by the gas industry includes a number of areas. We highlight two promising new approaches to industrial conservation. The first is thermochemical recuperation of high-temperature heat from industrial furnaces to preheat combustion air, for which a $3 million program is recommended to develop a sub-scale facility to evaluate design parameters, conversion rates, low-cost catalysts, and materials compatibility. The other is an advanced combustor concept for industrial applications that locates the heat exchange surface directly in the combustion zone and uses catalysts supported on these surfaces for combustion. A $2 million program is recommended to study a prototype design of this concept.

Hydrogen research through thermochemical or thermoelectrochemical cycles using nuclear fusion, fission, or solar energy as the high temperature heat source is recommended in a $3 million program, of which $1 million is assigned to evaluating three promising hybrid hydrogen cycles based on copper, zinc and cadmium chemistry.

Physical and Chemical Energy Storage

A promising means of storing energy is to store heat at elevated temperature, or thermal energy storage (TES). The energy can later be used for on-site commercial or industrial applications. One thermochemical method to accomplish TES is the use of melted salts or salt mixtures.

IGT recommends, within the Physical and Chemical Energy Storage category, $4 million for the development of thermal energy storage using composite molten-salt phase-change materials.

Thank you for the opportunity to present my views. I will be happy to answer your questions.

ATTACHMENT 1
TO STATEMENT BY BERNARD S. LEE
May 3,1983

For FY'84, IGT specifically recommends:

- $8 million for coal gasification supporting research
- $1 million for operating a pressurized ash agglomeration process research unit
- $1 million for component development
- $1 million for advanced gasification concepts
- $1 million for hot gas cleanup
- $2 million to develop the countercurrent free-fall retorting of fine-size oil shale
- $6 million for tight sands research
- $6 million for Devonian shale research
- $6 million for advanced unconventional gas research on deep-source gas and gas hydrates
- $12 million for geopressurized gas research
- $1 million for research using stress-relieving to stimulate gas flow from coal seams
- $2 million to complete work on the RENUGAS process research unit
- $2 million for converting high water-content biomass and wastes to fuel
- $1.5 million for the two-phase biological digestion of municipal sewage sludge and landfills to produce methane
- $1 million for biological gasification of woody biomass without pretreatment
- $1 million to initiate a regional biomass center at IGT
- $4 million for technology base enhancement of the molten carbonate fuel cell
- $1 million for hybrid hydrogen cycles evaluation
- $3 million for development of the thermochemical recuperative system
- $2 million for an advanced gas/solar desiccant system for heating and cooling
- $2 million for development of a catalytic surface combustor
- $4 million for development of thermal energy storage using molten salts

GASIFICATION

Coal

IGT recommends $8 million to carry out supporting research comprising: $0.5 million on the gasification mechanism of sulfur, nitrogen, and trace element contaminants contained in U.S. coals; $2 million for investigation of the dynamics of fluidized beds at high temperature and high pressure; $1 million on the behavior of coal ash during gasification; $0.5 million on the development of selective hydrogen sulfide removal using anhydrous organic solvents; $2 million for beneficiation of low-rank coals to reduce moisture and upgrade heating values; $1.5 million for compilation, evaluation and correlation of information relevant to all coal gasification processes in forms useful to engineers and scientists; and $0.5 million for bioprocessing of raw gasified effluent to remove sulfur and produce methane.

IGT also recommends:

- $1 million for extension of the ash agglomeration technique to higher pressures and lower rank coals using an existing facility

- $1 million for component development of a liquid-sealed lockhopper system for feeding coal into high pressure gasification systems, thereby eliminating gas compression and gas loss

- $1 million for advanced gasification concepts that utilize internal recirculation catalysts or carbon dioxide instead of steam as the gasifying agent to decrease the size and/or number of equipment items in any coal gasification process

- $1 million for hot gas cleanup using mixed metal oxide sorbents and other solid adsorbents to handle dusty and corrosive gases without conventional quenching.

Oil Shale

The fine particles resulting from preparation of oil shale for processing are currently discarded as a waste product. IGT recommends $2 million for development of countercurrent free-fall retorting (CFFR) of shale fines using an existing bench-scale facility. This process is applicable to eastern and western shales, and has the potential for improved energy efficiency, resource recovery and environmental compatibility.

UNCONVENTIONAL AND GEOPRESSURED RESOURCES

- IGT supports a $6 million program for tight sands. We propose a comprehensive program of core analysis, hydraulic fracturing and production testing of the depositional environments of the wells already drilled, along with the determination of the gas entrapment and production mechanisms of the wells.
- IGT strongly recommends $12 million for continuing production from the existing four geopressured wells with enhanced instrumentation and data interpretation in relation to natural gas in excess of that in solution in the brine. Further, we recommend DOE participate in a new well to test brine production for recovery of gas left in place after abandonment of water-drive gas reservoirs.
- For Devonian shale, IGT supports a $6 million program which would include our inputs to newly developed computer programs to gain a better fundamental understanding of factors that control gas content and gas flow.
- For advanced unconventional gas, IGT recommends a $6 million program for research on deep-source gas and hydrates and sediments, including means for measuring engineering parameters of hydrate deposits in nature.
- For methane from coal-seam, the DOE program should be expanded to include a new concept of opening horizontal channels in the coal to relieve pressure and stimulate gas flow, an approach that is potentially more effective than hydraulic fracturing. IGT specifically recommends $1 million to initiate work on this concept of applying limited combustion underground to remove sufficient coal to relieve stresses in the seams that will permit enhanced gas flow.

BIOMASS

- IGT recommends $2 million to complete the research program on the RENUGAS process, in which a pressurized fluidized-bed process research unit has been built with DOE funding, to obtain fundamental data for the thermochemical conversion of biomass and wastes to fuel gas or synthesis gas.
- $2 million for research on two approaches to make fuel from biomass and wastes of high water-content, which are not conducive to direct thermochemical conversion.
- $1 million to establish the potential of an important breakthrough, the first known inoculum which can biologically gasify woody biomass without pretreatment.
- In waste conversion, $1 million to construct and operate a process research unit for two-phase biological digestion of municipal sewage sludge.
- $0.5 million for bench-scale research on LANFILGAS process for biologically digesting landfills through controlled recirculation of special bacteria cultures.
- $1 million to initiate a regional biomass center at IGT, one of several such centers that should be established to focus on candidate biomass and waste feedstocks for a particular region and to coordinate local research and interest groups.

FUEL CELL

In the molten carbonate fuel cell area, IGT specifically recommends $4 million to initiate a multi-year program on technology base enhancement which focuses on using existing facilities for evaluating components, testing prototype endurance, measuring effect of contaminants, and preparing electrolytes in a controlled environment. The MCFC system has potentially the best combination of performance, efficiency, and cost to capture a significant portion of several end-use applications.

CONSERVATION

- IGT recommends a $3 million program to develop a sub-scale facility of the thermochemical recuperative system to evaluate design parameters, conversion rates, low-cost catalysts, and materials compatibility. Such a system could significantly increase the waste heat recovered from high-temperature furnaces through preheating of combustion air.
- $2 million to initiate a program to build and test in the laboratory the H-COP MEC concept for residential heating and cooling. This is an advanced high-efficiency concept based on a gas-fired, open-cycle, solid-desiccant system that can be coupled with a solar energy source.
- $2 million to develop an advanced industrial catalytic surface combustor for firing package boiler and process heaters which locates the heat exchange surface directly in the combustion zone and uses catalyst supported on the surface for combustion. A program to develop this combustor, having broad national implication in energy conservation and emission control, would include fabricating a prototype combustor and measuring the performance characteristics of the heat exchange catalyst material and surface.
- $1 million to experimentally evaluate the kinetics, product purification, process/energy source interface and engineering optimization of three promising hybrid cycles for hydrogen production.

PHYSICAL AND CHEMICAL ENERGY STORAGE

- IGT recommends $4 million for the development of thermal energy storage using composite molten-salt phase-change materials.

ATTACHMENT 2
TO STATEMENT BY BERNARD S. LEE
May 3, 1983

GASIFICATION

Coal Gasification

Supporting Research

o Fundamental information is needed on the gasification mechanism of heteroatoms such as sulfur, nitrogen, and trace element contaminants contained in U.S. coals. Isotopes of these heteroatoms can be used as labels to trace the conversion reactions and more accurately predict the particular contaminant species in the gasifier effluent. Such research will also provide the basic data needed to economically and efficiently process these contaminants in an environmentally acceptable manner.

IGT recommends $0.5 million in FY'84 to conduct research in this area.

o A critical need exists to investigate the dynamics of fluidized beds at high temperature and high pressure (up to 1000 psi and 2000°F). Fluidization data will be obtained on the potential synergistic effects of temperature and pressure on bubble size, bubble growth and the degree of solids mixing in order to fully understand gas-solids dynamics. Better definition of the combined effects of temperature and pressure will result in improved designs of fluidized bed gasifiers and the solids transport lines between reaction zones. Taking full advantage of a unique computer-assisted pressure probe analyzer, an existing fluidization test facility will be expanded as necessary to obtain data on a novel non-sintering oxygen distributor and its effect on jet penetration and the temperature profile within the jet.

IGT recommends $2.0 million in FY'84 to carry out this work.

o The behavior of coal ash during gasification strongly influences the reactor operability. Understanding the role of sulfur compounds and alkaline contaminants in coals on the formation of low-melting eutectics is essential to develop high carbon conversion gasifiers and high temperature dust removal equipment. Fundamental studies to monitor the changes in the physical and chemical properties of coal mineral matter under gasification conditions would employ existing equipment including bench-scale fluidized-bed reactors, a highly specialized pressurized hot-stage microscope, and an ash viscosity penetrometer.

IGT recommends $1.0 million in FY'84 to carry out this research.

o Highly selective hydrogen sulfide removal from coal-derived synthesis gas could significantly reduce the cost of sulfur management in coal gasification plants. Selective removal generates a highly concentrated stream which significantly improves conventional hydrogen sulfide conversion systems. Specific anhydrous organic solvents have been identified but require further development. These anhydrous solvents might also be used to clean up sulfur dioxide or hydrogen sulfide emissions from the sulfur plant tail gas, carbon dioxide vent gas, and steam plant flue gas. Using existing equipment, data will be obtained on the solubilities and heats of absorption of hydrogen sulfide and other synthesis gas components in the organic solvents at temperatures up to 200°F, and pressures up to 1000 psi, over the range of gas compositions anticipated in gasification processes, to optimize the process.

IGT recommends $0.5 million in FY'84 to carry out this work.

o Beneficiation of low-rank coals such as lignites and subbituminous coals to reduce moisture and upgrade heating value will improve gasifier productivity and enhance raw gas quality with attendant capital, operating, and product cost reductions. Wet carbonization can be used to accomplish these goals. Existing PRU-scale equipment at IGT can be used to determine the effects of temperature, pressure, residence time, particle size, and feedstock characteristics on moisture reduction and heating value enhancement.

IGT recommends $2.0 million in FY'84 to apply this technique to low-rank coals.

o In order to effectively transfer the results of Government supported technology development to the point of commercial application by private industry, it is necessary to compile, evaluate, and correlate information relevant to all coal gasification processes in forms useful to engineers and scientists. Much of the available data is based on empirical relationships which can deviate widely from actual systems. Additional data correlations are needed on the properties of coal, char, ash and slag, synthetic sorbents, and related organic compounds and gas mixtures. Also, new data must be acquired on multicomponent vapor liquid equilibria combined with chemical reactions for design purposes.

IGT recommends a funding level of $1.5 million to collect and compile data in the areas listed.

o A novel low-pressure, low-temperature process to upgrade raw gasifier effluent streams is now under study at IGT. This process consists of two steps. In the first step, bacterial action is used to convert synthesis gas directly to methane, thereby avoiding conventional catalytic water-gas shift and methanation reactors. In the second step, anaerobic bioprocessing converts hydrogen sulfide directly to sulfur, thereby avoiding sulfur removal and regeneration equipment. Further development work of the total process at the laboratory and bench-scale level is required to establish the effects of reactor size and type, temperature, pressure, gas flow rate, and gas composition on conversion efficiency so that the optimum operating conditions of these two bio-reactors can be determined.

IGT recommends $0.5 million in FY'84 for research in this area.

Pressurized Ash Agglomeration Process Research Unit

The technique of ash agglomeration affords very high conversion efficiency in producing gaseous fuels from coal. This technique has been proven in large equipment with bituminous coals. IGT proposes to extend this technique to higher pressures and lower rank coals. Using an existing 8-inch-diameter ash agglomerating PRU reactor, lignites and subbituminous coals can be tested at pressures up to 500 psi. High pressure is more favorable for the production of chemicals, methanol and SNG. This 8-inch process research unit is large enough to generate data that are reliable and closely simulate large-scale operating conditions.

IGT recommends $1.0 million in FY'84 to conduct research in this area.

Component Development

Conventional lockhopper technology uses process gas or steam to feed coal into high pressure gasification systems. This results in rather costly and inefficient compression systems and unavoidable loss of product gas. A liquid sealed lockhopper system eliminates gas compression and gas loss. An existing PRU-scale water-sealed lockhopper system will be used to extend this technique to coal. Experimental data will be obtained to determine the effects of particle size, liquid medium, coal type and feed rate.

IGT recommends $1.0 million in FY'84 for research in this area.

Advanced Gasification Concepts

IGT proposes two advanced coal gasification concepts that offer the potential of decreasing the size and/or number of equipment items in a conventional coal gasification process.

The development of an internal recirculation catalyst to enhance coal gasification kinetics in the range of 500° to 1500°F would result in a high efficiency process with low tar formation. Existing laboratory equipment has been used to identify several volatile catalysts which, with further development, could significantly improve conventional gasification process designs.

Gasification with carbon dioxide rather than steam offers the potential of system flexibility and more favorable economics. The range of available data needs to be extended to allow full evaluation of this concept.

IGT recommends $1.0 million in FY'84 to conduct this research.

Hot Gas Cleanup

Downstream gas processing schemes that avoid conventional quenching and are capable of handling dusty and corrosive gases would improve overall coal gasification efficiency, economics, and environmental acceptability. Selective removal of corrosive acid-gas species and subsequent conversion to useful coal by-products can achieve these goals.

Several specific areas are immediately important. High temperature fuel gas desulfurization can be accomplished with mixed metal oxide sorbents that can produce sulfur directly upon regeneration, thereby avoiding sulfur dioxide scrubbing and/or reduction systems. Likewise, selective removal of carbon dioxide at high temperature can be accomplished with solid adsorbents that have been identified in exploratory laboratory experiments. Available equipment can be used to study the effects of gas composition, pressure, and temperature on removal efficiency and sorbent behavior.

These studies, coupled with a program to develop a water-gas shift catalyst that can function under conditions of high dust loading, combine to create a comprehensive program aimed at high temperature, raw gas processing that would avoid the costly and thermally inefficient quench step.

IGT recommends $1.0 million to carry out this work in FY'84.

Oil Shale Fines Gasification

The fine particles resulting from the preparation of oil shale for processing are difficult to process for energy recovery and are normally discarded as a waste product. IGT is now directing its efforts toward developing an advanced gasification process which could utilize this potential energy resource. This CFFR process concept is the Countercurrent Free-Fall Retorting of fine particles of oil shale, a technique applicable to all oil shales, Eastern or Western.

The CFFR process is an energy-efficient and environmentally compatible method for increasing the overall shale resource recovery. The equipment required is simple and the gas produced is of high quality, therefore reducing downstream processing steps. For handling shale fines, IGT expects the CFFR process to be superior to fluidized bed or entrained flow retorting schemes. It could be used as a stand-alone process or as an adjunct to another process that cannot utilize fine particles.

IGT recommends $2 million for FY'84 for the development of the CFFR process concept, which can be initiated in an existing bench-scale facility.

UNCONVENTIONAL AND GEOPRESSURED RESOURCES

Tight Sands

Unconventional gas derived from the so-called tight sands refers to natural gas trapped in sandstone formations of variable porosities and permeability when compared with more conventional reservoirs. In FY'83, in a limited program, IGT analyzed core samples from the first two wells of the multi-well experiment in Colorado using our high resolution Computer Operated Rock Analysis Laboratory (CORAL). The matrix permeability of the rock, as accurately measured by CORAL, was found to be much lower than anticipated. However, initial production tests showed a much higher flow rate than would be expected on the basis of these matrix permeabilities. Some authorities have suggested that most tight sandstone production may be due to natural fractures. This is in strong contrast to prior conceptions and the assumptions in the multi-well experiment design. It is hypothesized that natural fractures may be responsible for the high initial flow rate of gas production from tight sands, which is followed by the much reduced flow rate due to matrix porosity and permeability. Also, greater gas content and permeability may exist in geologic zones between those previously targeted for hydraulic fracturing experiments. However, continued research is required on both in-situ gas content and in-situ permeability of sandstones with particular emphasis on better defining in-situ water content, which inhibits gas flow. For FY'84 we propose a comprehensive program of core analysis, hydraulic fracturing and production testing of the depositional environments of the wells already drilled. Additionally, determination of the gas entrapment and production mechanisms of the wells would be included in the $6 million program.

Devonian Shale

The need exists for a better fundamental understanding of factors that control gas content and gas flow in Devonian shale. Modest electronic modifications of our computer-operated rock analysis laboratory provide the increased resolution and sensitivity required for measurements and analysis of reservoir properties needed as inputs to newly developed computer programs at METC which incorporate the fundamental factors. We look forward to active participation in this work as a part of a $6 million DOE program.

Advanced Unconventional Natural Gas

In the area of deep-source gas, the various hypotheses as to the origin of such gas must be examined. Deep-source methane could originate from primordial methane trapped during the formation of the earth, or could be formed thermochemically from inorganic carbon and hydrogen in volcanic rocks. On the other hand, deep-source methane may be biologic in origin, but trapped deeply as material in the ocean floor is moved, or subducted, under continents due to plate tectonics. Much needs to be understood about this methane source because the implications of the earth's remaining methane resource could depend on the correct interpretation. Research efforts should be expanded to collect and analyze available geological, geochemical, and geophysical data to systematically assess the plausibility of various hypotheses. With improved knowledge of the origin of this gas resource, a much better understanding of how to develop it will result. This would be a cost-effective approach before field sampling and coring are undertaken.

In exploring methane hydrates, IGT's fundamental laboratory work has indicated that hydrates may have important roles in forming conventional gas reservoirs in both arctic and deep-ocean areas. But much additional laboratory research is required on fundamental properties of hydrates in sediments, and for development of tools to determine whether mobile fluids co-exist with the hydrates. Substantiation of this would greatly improve economics of production.

IGT, therefore, supports a $6 million advanced unconventional gas research program on deep-source gas and methane hydrates in sediments, specifically including means for measuring engineering parameters of hydrate deposits in nature.

Geopressured Methane

IGT strongly recommends $12 million funding for continuing production from the existing four geopressured wells through FY'84 and that additional and enhanced instrumentation and data interpretation be directed to more accurate determination of the gas water ratio. Further, we recommend DOE participate in a new well to test brine production for recovery of gas left in place after abandonment of water-drive gas reservoirs. IGT has identified locations where an estimated 4 trillion cubic feet of natural gas was abandoned in place because brine disposal costs could not be recovered at the then-existing natural gas price.

Methane From Coal Seams

Fifteen years of mine safety research plus a modest DOE program during the last four years have clearly shown that hundreds of trillion cubic feet of potentially producible methane exists in coal seams in the U.S. However, with the exception of the Warrior Basin in Alabama, application of conventional gas well completion and coal mine drainage technologies have provided minimal incentive for risk capital investment by industry. Work at IGT provides the basis for a strong belief that the DOE program be expanded to include a new approach to exploit the energy supply from this source. IGT's research on gassy coal seams has revealed that opening of horizontal channels in the coal to relieve pressure could be more effective than hydraulic fracturing for stimulation of methane production. One possible means for doing this is by high pressure in-situ combustion techniques such as used to link wells prior to in-situ coal gasification. Once these horizontal channels are opened, gas pressure in the coal seams would then be reduced by producing the well, causing the flushing of combustion products from the channel, relaxation of stress in the coal seams, and much higher long-term production rates than possible with hydraulic fracturing.

IGT recommends $1 million in FY'84 to further work on this concept, by extensive laboratory analysis of coal core samples, coupled with computer simulation of stress relaxation in the coal. Such information would allow an effective planning of field tests which may be conducted independently or piggy-backed onto other related field tests.

BIOMASS

Biomass Conversion

o The IGT RENUGAS Process Research Unit (PRU) is a pressurized adiabatic fluidized reactor system built with DOE support. It is specifically designed and instrumented to obtain fundamental data for the thermochemical conversion of biomass and wastes to fuel gas or synthesis gas. To derive maximum benefit from this area of research, fundamental kinetics of biomass gasification must be obtained which will be combined with mass, momentum and heat transfer parameters of biomass gasifiers to develop computer-assisted process simulation models. These models for stationary and mobile applications will be validated with the RENUGAS PRU test results. $2 million is needed to complete this research program and identify trends in gasification characteristics, reactant requirements, and environmental aspects of thermochemical biomass gasification.

o For biomass of high water-content which are not conducive to direct thermochemical conversion, two promising approaches have been identified to make these feedstocks suitable for thermochemical conversion. One approach involves a two-step biothermal gasification process that first applies biological gasification to the feedstocks which not only produces methane, but also renders the residue suitable for the subsequent thermochemical gasification. IGT has initiated development of this process and further basic and bench-scale research is needed to define the key process parameters. The other approach is wet carbonization which improves both the dewatering characteristics, lowers the oxygen content, and increases the heating value of the feedstock. The wet carbonization is carried out at temperatures of 350° to 550°F and pressures high enough to prevent vaporization of water. Existing PRU-scale equipment at IGT can be used to determine the temperature, pressure, residence time, particle size, and feedstock characteristics on moisture reduction and heating value enhancement. IGT recommends $2 million in FY84 for conducting the necessary research in these two approaches.

o IGT has recently developed the first known inoculum which can biologically gasify woody biomass without pretreatment. This discovery should be further evaluated for a variety of woody species to fully establish the potential of this important breakthrough which could significantly advance biological converson of all woody biomass. IGT recommends $1 million to determine the effects on biodegradability and gas yields of feedstock composition and concentration, residence time, temperature, and inoculum type and concentration at the laboratory and bench scale. Genetic engineering techniques would be used to develop hybrid inocula which have high conversion capabilities. These inocula, once developed, would be incorporated into IGT's two-phase digestion process tailored to wood conversion.

Waste Conversion

Disposal of wastes is a growing problem in all communities throughout the United States. IGT has been developing a two-phase biological digestion process than can be used to recover energy from such wastes while simultaneously stabilizing the residue and rendering it more suitable for disposal.

o In a current laboratory study IGT is testing its two-phase digestion process with municipal sewage sludge. The data to date indicate that over 5-1/2 cubic feet of methane can be produced for every pound of dry organic matter processed. A novel upflow solids digester is showing good promise as the digester type to be used for sludge. The next logical step is to construct and operate a continuous, adiabatic larger scale process research unit. Continuous on-site testing is necessary to prove the upflow reactor concept.

IGT recommends $1.0 million to construct and operate an on-site PRU to prove its two-phase digestion process for municipal sewage sludge.

o Two-phase biological digestion can also be used to recover energy from solid waste landfills. IGT's LANFILGAS process uses controlled recirculation of a specially developed bacterial culture to stabilize the organic waste within the landfill and to produce methane by two-phase digestion of leached organics in the recirculating culture. The process can be applied to large as well as small landfills. Small-scale laboratory data indicate the technical feasibility of the concept. Further data are needed at the bench-scale level to study the effects of culture recirculation rate, digester temperatures, and hydraulic and solids retention times in the acid-phase and methane-phase digesters.

IGT recommends $0.5 million to carry out bench-scale research on the LANFILGAS process.

Biomass Growth and Harvest

Terrestrial and marine biomass represents renewable energy resources that have the potential for making a significant contribution to our energy base. Growth and harvesting have significant impact on the overall concept of using biomass for energy. Multiple-use species (where a portion of the plant is used for energy and a portion for food), such as sorghum and energy cane, should be studied to optimize their composition and yield. Consideration should be given to species with extensive root systems that prevent soil depletion. Development of woody species native to the northern states should be continued using short rotation farming techniques. These could provide a major energy crop base in those states where the yield of other biomass species are limited by colder temperatures.

IGT supports a $5 million effort for several research and development projects that would focus on optimizing crop yield and composition through genetic engineering, and on developing improved harvesting methods.

Biomass Regional Centers

A number of regional biomass centers should be established which focus on candidate biomass and waste feedstocks for a particular region and which coordinate local research and interest groups, including government, industry, universities, and the general public. The centers would organize seminars, work shops, and conferences, and compile documents for dissemination of information. Since IGT has been in the forefront of all aspects of biomass development, from feedstock growth, harvesting, conversion, to assessment and information dissemination, $1 million for FY'84 is recommended to initiate such a regional biomass center at IGT.

FUEL CELL

Molten Carbonate Fuel Cells

Numerous comparative system studies have shown that the molten carbonate fuel cell (MCFC) has potentially the best combination of performance, efficiency, and cost to capture a significant portion of several end-use applications. Therefore, sufficient funding must be allocated toward developing the MCFC system to the stage where these projections of cost, performance, and efficiency can be reliably established.

IGT proposes a multi-year program, and recommends $4 million for FY '84 to further the program. Major tasks are as follows:

- Utilize existing facilities and capabilities to develop, test and evaluate innovative fuel cell components such as the electrolyte, anode, reforming catalyst for internal reforming cells, and the cathode and bipolar plate; endurance testing of bench-scale cells and stacks of cells; and carbonate management schemes and stack design. Using existing DOE facilities for testing prototype endurance, for measuring the effect of contaminants on cell performance, and for electrolyte preparation in a controlled environment would be cost effective and would provide impartial dissemination of information on cell life and performance directly to all potential manufacturers.
- Basic electrochemistry and accompanying support studies.
- Systems analysis of power plant designs and configurations, including performance modelling, gasifier selection, feasibility of anode gas recycle and establishment of fuel tolerance.

CONSERVATION

Advanced Gas Prime Movers

IGT supports a $4 million research program for developing advanced gas prime movers. There are many sound reasons for developing natural gas-fueled internal combustion engines. The high octane number of natural gas as a fuel provides superior anti-knocking characteristics which allow for high compression-ratio designs and thus highly efficient engines. Natural gas is a fuel that combusts cleanly, leaving no residual hydrocarbons, thereby greatly reducing the emission of pollutants to the air compared with conventional engines using liquid fuel. The clean burning characteristics of natural gas extend the life of the lubricant and the engine, leading to lower operating costs. Most importantly, natural gas is widely distributed and is much cheaper than liquid petroleum engine fuels. The broad deployment of natural gas-fueled engines will be beneficial to the nation in reducing its demand for oil.

One area of broad application is in small engines that provide on-site power generation and space conditioning in commercial and industrial installations. These engines, currently operated typically on diesel fuel, can be readily replaced by natural gas-fueled engines. These installations typically have natural gas service so that no fuel storage needs to be provided. IGT plans to actively participate in the development of a reliable and efficient small engine for natural gas.

Thermochemical Recuperator

IGT has developed a waste-heat recovery system for high temperature industrial furnaces (for example, in the fiber glass and steel industries) that could significantly increase the waste heat recovered from these furnaces through preheating of combustion air. Currently available metallic recuperators are limited to about 1500°F in air preheat. Work is underway to develop ceramic heat exchangers to increase this to 2000°F. The IGT approach, however, uses no exotic ceramics. Instead, it recuperates the high-temperature waste heat, through a metallic heat recovery system, via the thermochemical conversion of natural gas with steam. The resulting synthesis gas mixtures, when combusted with air preheated by state-of-the-art technology,is equivalent to an air preheat of 2200° to 2600°F.

The benefits of the proposed TCRS (Thermochemical Recuperative System) are —

- Waste-heat recovery efficiencies exceeding 70% (depending on process conditions) as compared with only 30% to 40% for conventional recuperation.
- Fuel savings of up to 30% above that achieved by conventional recuperation.
- Reductions in flue-gas volumetric flow because of reduced fuel consumption which enable reducing other operating costs such as parasitic power requirements for stack ejector fans or using smaller furnace stacks. The reduction of flue-gas pressure drops may be as much as 50%.

- Increases in furnace production rate and improved production quality due to enhanced flame temperature and the higher combustion gases radiation that results from increased water vapor concentration in these gases.

- NO_x emission abatement per unit of product produced due to higher heat flux to the product, higher thermal furnace efficiency, and an increase in furnace production rate compared with conventional heat recovery practice.

IGT recommends $3 million to develop a sub-scale facility of the TCRS to evaluate design parameters, conversion rates, low-cost catalysts and materials compatibility. The results will lead to a test program of a large scale prototype at an industrial site.

Desiccant Systems

The past several years have seen the emergence of open-cycle solid desiccant processes as the most attractive alternative to conventional air-conditioning systems when coupled with a solar energy supply system. By design, the system is reasonably compact, simple, and inexpensive; utilizes no exotic materials or technology; and its operation is intrinsically safe and of potentially long life with moderate servicing.

An advanced gas-solar- or gas-only-fueled desiccant system, the H-COP MEC, was developed by IGT for residential heating and cooling. This design features a 95% efficient heat exchanger wheels and advanced reactivation design. The calculated seasonal "energy efficiency ratio" (EER) is twice that of commercially available air conditioning systems, and the projected cooling performance exceeds that of other systems now under development by more than 50%.

A funding of $2 million is recommended to initiate a program to build and test in the laboratory the H-COP MEC concept in a configuration for residential use, including gas-only and gas/solar firing, and the attendant desiccant technology development.

Industrial Catalytic Surface Combustor

An advanced combustor concept, particularly applicable to package boilers and process heaters, has been developed which locates the heat exchange surfaces directly in the combustion zone and uses catalyst supported on these surfaces for combustion. Such a combustor would reduce the peak flame temperature substantially, thereby significantly reducing NOx formation, which is a principal pollutant in the flue-gas emissions. Furthermore, such a combustor would improve the heat-transfer rates and efficiency, and reduce the combustor size, all of which would mean substantial reduction in capital and operating costs.

This conceptual combustor design has broad national implications in energy conservation and emission control. To evaluate this concept, it is necessary to perform research and development on heat exchanger materials, preparation and treatment of the combustor heat exchanger surface, catalyst formulation and deposition, and catalyst life. After the laboratory research phase, it will be appropriate to fabricate a prototype catalytic surface combustor and measure its actual performance characteristics. $2 million is recommended for this program.

Hydrogen

A candidate alternative future energy form is hydrogen, which can be made from water by supplying primary energy from solar, fission or fusion sources, and which reverts to water on use. This hydrogen could be transported, stored, and distributed in the existing natural gas systems; it could supply much of society's need for a chemical fuel for heating and transportation; and it could be a basic feedstock for the chemical and petrochemical industry. To make this concept feasible, the need for an improved water-splitting process for producing the hydrogen is critical.

Thermochemical or thermoelectrochemical hydrogen produced by efficient cyclical processes using nuclear fission, fusion, or solar energy as the high-temperature heat source offers an energy conversion route that is flexible, is less dependent on (or even independent of) electric power generation, and has achieved proof-of-concept in various laboratory-scale projects. Thermal, or hybrid, cycle systems take in water as a feedstock, use recycled chemical intermediates, and produce hydrogen that eventually returns to the environment as water. As a future fuel, hydrogen produced by decomposing water with a series of chemical steps, using high-temperature solar or nuclear heat, could provide a large and cost-effective supply of hydrogen.

Three very promising hybrid hydrogen cycles that have been proven on a laboratory scale are based on copper sulfate-copper oxide, zinc sulfate-zinc oxide, and cadmium chemistry. However, in order to advance this technology to the demonstration stage, additional fundamental work must be done on the kinetics, product purification, process/energy source interface and engineering optimization of these processes. It is therefore necessary that a sustained basic research support be available for this work. IGT supports a $3 million program in FY '84 for hydrogen research, and specifically recommends $1 million for hybrid hydrogen cycles evaluation.

PHYSICAL AND CHEMICAL ENERGY STORAGE

Thermal Energy Storage

Conventionally, relatively large amounts of energy are stored as fuels in their natural or refined chemical forms. Another promising means of storing energy is to store heat at elevated temperature, or thermal energy storage (TES). This energy can later be used for on-site commercial or industrial applications, partially offsetting the use of gaseous or liquid fuels. One thermochemical method to accomplish TES is the use of melted salts or salt mixtures.

Before widespread application of molten salts TES is possible, a broad-based generic research and development program should be undertaken to investigate the many applications and operating requirements and the many storage media configurations possible. This program would include measurement of the physical and chemical properties of potential media materials, optimization of media thermal and physical behavior within expected operating conditions, media selection and development to fit application temperatures and operating requirements, and materials compatibility studies of media containment, working fluids and auxiliary components.

IGT recommends, within the Physical and Chemical Energy Storage category, $4 million for the development of thermal energy storage using composite molten-salt phase-change materials.

Senator **Ford** [presiding]. Thank you very much. I think you are getting a variety of show-up's here. We expect you to put on one, Carl, in a minute. God bless, Carl.

Mr. **Bagge**. God bless, Senator.

Senator **Ford**. Sidney H. Law, chairman, Communications and Member Relations Subcommittee, Fuel Cell Users Group, Hartford, Conn.

STATEMENT OF SIDNEY H. LAW, MEMBER, MANAGEMENT COMMITTEE, FUEL CELL USERS GROUP OF THE ELECTRIC UTILITY INDUSTRY, INC.

Mr. **Law**. Thank you, Mr. Chairman. In the interest of time, I will be summarizing my testimony. I ask that it be adopted in its entirety in the record.

Senator **Ford**. Without objection, it will be included in the record.

Mr. **Law**. The Fuel Cell Users Group of the Electric Utility Industry appreciates this opportunity to present these brief remarks on the 1984 Department of Energy fuel cell budget.

I am Sidney Law, director of research at Northeast Utilities Service Co. in Hartford, Conn., and a member of the Management Committee of the Fuel Cell Users Group.

Mr. Chairman, I know you appreciate the outstanding potential of the fuel cell technology since you and this committee have been consistent, strong supporters of the fuel cell for many years. I, therefore, will not go into the many advantages although these are included in the testimony.

I do want to say, however, that the promise of the fuel cell remains high. To achieve that promise by the end of this decade, sustained partnership will be required between the Federal Government, the prospective manufacturers, and all sectors of the utility community. This means striving to achieve some level of consistency in the Federal funding profile rather than the annual roller coaster effect that has characterized the program through recent years, and to maintain the strong, cooperative spirit that now exists between the public and private partners in this effort.

We estimate that the funding requirement for the Federal fuel cell program in fiscal year 1984 is $35 million. While this is in stark contrast to the administration's $9.5 million request, it is virtually identical to the average fuel cell budget for the last 6 fiscal years, so our request clearly complies with the President's plea for a spending freeze in fiscal year 1984.

Of this $35 million total, at least $22 million should be made available for the electric utility phosphoric acid fuel cell base programs currently underway, and to bring to satisfactory completion the 4.8 megawatt project in New York City. This is the level of support formally endorsed by the membership of the users group in approving the attached resolution on DOE phosphoric acid fuel cell funding. It is also the amount already contractually obligated by the Department of Energy to the potential venders.

In order to support basic research in phosphoric acid and advanced concept fuel cell powerplant materials and processes we strongly urge the committee to provide $6 million in advanced research and technology development funds. No less than $4 million of this would be provided to the private sector for technology advancement of phosphoric acid fuel cells.

Specific areas of investigation would be catalyst development with higher performance and/or lower utilization of strategic materials; development of materials, processes, and/or replenishment concepts to provide extended acid life; development of advanced fuel cell materials and fabrication processes for electrodes, separators, and cooling components; development of more efficient and durable fuel cell electrode structures; development of improved fuel processing techniques; and development of advanced control technology.

Private sector R&D contributions for fiscal year 1984, meanwhile, are expected to remain higher than Federal outlays, approaching the roughly 2-to-1 ratio maintained through the history of the fuel cell program. Through 1982, DOE funding totaled $95 million with the private sector share at $184 million.

Furthermore, the negotiations presently underway regarding four or five prototype fuel cell demonstrations represent an additional private sector expenditure of more than $300 million. The utilities individually and through the Electric Power Research Institute as well as the prospective manufacturers are keeping steadfast in their commitment to the fuel cell in general and in their resolve for early commercialization of the multimegawatt phosphoric acid fuel cell in particular.

Mr. Chairman, I thank you and the committee for your longstanding support of this attractive technology. I encourage your continued funding for the next few years, and I appreciate the time to present these remarks.

[The prepared statement of Mr. Law follows:]

STATEMENT ON THE FY 1984 FUEL CELL BUDGET
OF THE DEPARTMENT OF ENERGY

Presented to the
SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT
of the
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
United States Senate

by the
FUEL CELL USERS GROUP OF THE ELECTRIC UTILITY INDUSTRY, INC.
May 3, 1983

Mr. Chairman, thank you for this opportunity for the Fuel Cell Users Group of the Electric Utility Industry, Inc. (the Users Group)[1] to present these brief remarks on the FY 1984 Department of Energy fuel cell budget. I am Sidney Law, Director of Research at Northeast Utilities Service Company in Hartford, Connecticut.

Mr. Chairman, I know you appreciate the outstanding potential of the fuel cell technology, since you and this Committee have been consistent, strong supporters of the fuel cell for many years. The advantages of high efficiency, low environmental impact, short lead time, fuel flexibility, cogeneration, modularity, and responsiveness combine to make the fuel cell one of the more exciting energy options for the 1990s and beyond.[2] There are also notable socioeconomic arguments that can be made in favor of the fuel cell, in view of the constructive role it could play at local, regional, and national levels. These points have been summarized in the attached letter (Attachment 2) to Secretary Hodel of the DOE from Mr. Lelan Sillin, Jr., Chairman of the Users Group. They are also summarized in the Resolution in support of "Research for Growth and National Security" passed by the Membership of the National Rural Electric Cooperative Association (NRECA) at its 41st Annual Meeting, January 30-February 3, 1983 and also attached (Attachment 3).

The promise of the fuel cell remains high. To achieve that promise by the end of this decade, sustained partnership will be required between the Federal government, the prospective manufacturers, and all sectors of the utility community. This means striving to achieve some level of consistency in the

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[1] The Fuel Cell Users Group of the Electric Utility Industry, Inc. is a three-year-old organization with a membership of 55 utilities (and eight Associate Members) spanning the privately, publicly, and cooperatively owned electric utility industry. A list of our membership is included as Attachment 1. Cumulatively, the members of the Users Group supply about 40% of the electric energy in this country. We are united in the interest of encouraging and supporting research, development, and demonstration leading to the ultimate commercialization of the phosphoric acid fuel cell power plant.

[2] In his recent statement before the Science and Technology Committee, Mr. Jan Mares, Assistant Secretary of the DOE for Fossil Energy, referred to the fuel cell as "a revolutionary hydrocarbon fuel conversion technology to increase the cost-effective, efficient, and environmentally acceptable use of conventional and alternative hydrocarbon fuels, thereby reducing demand for oil."

Federal funding profile--rather than the annual "roller coaster" effect that has characterized the program through recent years--and to maintain the strong, cooperative spirit that now exists between the public and private partners in this effort.

We estimate that the funding requirement for the Federal fuel cell program in FY 1984 is $35 million. While this is in stark contrast to the Administration's $9.5 million request, it is virtually identical to the average fuel cell budget for the last six fiscal years; so our request clearly complies with the President's plea for a spending freeze in FY84.

Of this $35 million total, at least $22 million should be made available for the electric utility phosphoric acid fuel cell base programs currently underway and to bring to satisfactory completion the 4.8 MW project in New York City. This is the level of support formally endorsed by the Membership of the Users Group in approving the attached "Resolution on DOE Phosphoric Acid Fuel Cell Funding" (Attachment 4). It is also the amount already contractually obligated by the Department of Energy to the potential vendors (the United Technologies Corporation and Westinghouse).

At 63% of the total fuel cell budget, $22 million represents a slightly higher proportion of spending for phosphoric acid than the 58% in the FY83 program. Yet it is significantly below the 81% dedicated to phosphoric acid by the Japanese in their aggressive fuel cell research, development, and demonstration program.

Our continuing strong interest in the development of the phosphoric acid fuel cell is based on the comparative readiness of this technology and the presence of committed U.S. companies in the area, which will help provide an efficient, competitive environment for the ultimate commercialization of this attractive alternative technology. As detailed in the findings of the "Planning Information Report for Development of Multi-Megawatt Fuel Cell Power Plants" (March, 1983) prepared for the Department of Energy by the Users Group, the DOE program needs to focus on the multi-megawatt phosphoric acid portion of the overall effort until success is in hand.

In order to support basic research in phosphoric acid and advanced concept fuel cell power plant materials and processes, we strongly urge the Committee to provide $6 million in advanced research and technology development funds. No less than $4 million of this would be provided to the private sector for technology advancement of phosphoric acid fuel cells. Specific areas of investigation would be: (1) catalyst development with higher performance and/or lower utilization of strategic materials; (2) development of materials, processes, and/or replenishment concepts to provide extended acid life; (3) development of advanced fuel cell materials and fabrication processes for electrodes, separators, and cooling components; (4) development of more efficient and durable fuel cell electrode structures; (5) development of improved fuel processing techniques; and (6) development of advanced control technology.

Private sector R&D contributions for FY84, meanwhile, are expected to remain higher than Federal outlays, approaching the roughly 2:1 ratio maintained throughout the history of the fuel cell program. (Through 1982, DOE funding totaled $95.1 million with the private sector share at $184.1 million.) Furthermore, the negotiations presently underway regarding four or five prototype fuel cell demonstrations represent an additional private sector expenditure of more than $300 million. The utilities--individually and through the Electric Power Research Institute--as well as the prospective manufacturers are keeping steadfast in their commitment to the fuel cell, in general, and in their resolve for early commercialization of the multi-megawatt phosphoric acid fuel cell, in particular.

Mr. Chairman, I thank you and the Committee for your longstanding support of this attractive technology. I encourage your continued funding for the next few years. And I appreciate the time to present these remarks.

Attachment 1

FUEL CELL USERS GROUP MEMBERS

Adams Electric Cooperative

Allegheny Electric Cooperative

American Public Power Association

Anchorage Municipal Light & Power

Arizona Public Service Company

Baltimore Gas & Electric Company

Basin Electric Cooperative

Boston Edison Company

Brazos Electric Power Cooperative

Buckeye Power, Inc.

Central Hudson Gas & Electric Corp.

Central Illinois Light Company

Colorado Ute Electric Assn., Inc.

Consolidated Edison Co. of NY

The Dayton Power & Light Company

Delmarva Power & Light Company

Easton Utilities Commission

Edison Electric Institute

Electric Power Research Institute

Green Mountain Power Corporation

Hawaiian Electric Company

Hoosier Energy Division, REC, Inc.

Hydro-Quebec

Idaho Power Company

Jacksonville Electric Authority

Kansas City Power & Light Co.

Lee County Electric Cooperative

Lincoln Electric System

Long Island Lighting Company

Massachusetts Municipal Wholesale
Electric Company

Memphis Light, Gas, and Water Division

Mississippi Power & Light Company

Missouri Basin Municipal Power Agency

National Rural Electric Cooperative
Association

Niagara Mohawk Power Corporation

Northeast Utilities Service Co.

Ohio Edison Company

Ontario Hydro

Philadelphia Electric Company

Provo City Power

Public Service Company of Oklahoma

Public Service Electric & Gas Co.

Rural Electrification Administration

San Diego Gas & Electric Company

Santa Clara Electric Department

Seminole Electric Cooperative

Southern California Edison Company

Southern Company Services, Inc.

Southern Maryland Electric Coop.

Tampa Electric Company

Taunton Municipal Lighting Plant

Tennessee Valley Authority

Toledo Edison Company

United Power Association

Virginia Electric Power Company

Associate Members

Burns & McDonnell Engineering Company

Burns & Roe, Inc.

Ebasco Business Consulting Services, Inc.

Johnson Matthey Research Centre

Kinetics

New Energy Development Organization

NUS Corporation

Stone & Webster Engineering Corporation

Attachment 2

THE FUEL CELL
USERS GROUP
OF THE ELECTRIC UTILITY INDUSTRY, Inc

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BOARD OF DIRECTORS

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Chairman and Chief Executive Officer
Public Service Electric and Gas Company

Bernard C. Trueschler
President
Baltimore Gas & Electric Company

Robert A. Bell
Vice President
Consolidated Edison
Chairman, Management Committee

Robert W. Fri
President
Energy Transition Corporation
Executive Director

January 31, 1983

The Honorable Donald P. Hodel
Secretary
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear ~~Secretary~~ Don Hodel:

I am writing to introduce the Fuel Cell Users Group of the Electric Utility Industry, Inc. and to discuss the continuing need for a strong partnership between the Federal government and the utility industry for the advancement of the fuel-cell technology.

The Users Group is a three-year-old organization with a membership of 55 utilities (and 8 Associate Members) spanning the privately, publicly, and cooperatively owned electric utility industry. Cumulatively, the members of the Users Group supply about 40% of the electric energy in this country. We are united in the interest of encouraging and supporting research, development, and demonstration leading to the ultimate commercialization of the phosphoric acid fuel-cell power plant.

You're probably aware of many of the features of the fuel cell that make it attractive to utilities. Among these are:

1. High efficiency (projected to be greater than 40% for electricity production)
2. Environmental compatibility
3. Short lead time
4. Fuel flexibility
5. Cogeneration potential (resulting in combined heat and power efficiencies exceeding 80%)

6. Siting flexibility
7. Modular construction
8. Reduced capital requirements for plant and transmission/distribution equipment
9. Fast transient response
10. Load-following capability
11. Decreased requirements for spinning capacity reserves
12. Reduced line losses
13. Automatic operation
14. Improved power system stability

These items are discussed in more detail in the enclosed guide, "Fuel Cell Power Plants for Dispersed Generation," from the Electric Power Research Institute.

Beyond these mechanical and operational characteristics there are a number of important social and economic questions that deserve consideration. A discussion of the fuel cell in the context of these broader issues is appended for your consideration.

These many compelling advantages--technical and socioeconomic--of the fuel cell over other generating systems factored heavily in the Congress' continued support of federal funding for all fuel cell activities in the range of $30-35 million per year for the past several years. However, DOE budget requests have not been equally stable, and so the fuel cell budget is subject to the "roller-coaster" effect you noted during your confirmation hearings. Needless to say, I'm encouraged by your resolve to control these funding transients and provide stability and consistency in the Department's programs.

These same attractive fuel-cell attributes also inspired the Energy and Water Subcommittee of House Appropriations to target fuel-cell based cogeneration as one of two technical initiatives (the other being heat pumps) particularly worthy of consideration by the Bonneville Power Administration under the mandates of the Regional Power Planning and Conservation Act.

The private sector (here consisting of all segments of the utility industry, the Electric Power Research Institute, and prospective fuel-cell manufacturers) is seriously committed to advancing the fuel cell to commercial status. As evidence of the level of our commitment, over the past ten years the private sector partners have spent about two dollars for every dollar of federal expenditure, a ratio that is expected to be maintained in the future.

Moreover, as vital research and development continue on the fuel-cell concept and components, progress is being made on the demonstration of four or five early prototype fuel cells. These efforts (at privately, municipally, and cooperatively owned utilities--Southern California Edison and Niagara Mohawk Power Corporation, New York; Santa Clara, California, Electric Department; and the United Power Association in Minnesota; respectively) are being pursued above and beyond the testing of 4.8 MW fuel-cell systems at Consolidated Edison Company in New York and the Tokyo Electric Power Company. It is anticipated that these new initiatives may represent more than $300 million in utility outlays.

It is through a strong, sustained partnership that these various current and anticipated endeavors will bring to fruition this promising technology. Programmatic, as well as fiscal support is required. As we proceed in our R,D&D activities and look toward fiscal year 1984, I hope the industry and the Users Group, in particular, can count on the cooperation of the fuel-cell and advanced research and technology development programs of the Fossil Energy Office and a consistent level of funding near those of FY-82 or FY-83 (in the range of $30-$35 million). Our request, by the way, is fully in accord with the President's recent appeal for a spending freeze in FY-84; it would indeed hold the line on--if not slightly decrease--real outlays for the fuel-cell program.

I'd like to note, in reflecting on the recent State of the Union message, that the fuel cell is a prime example of the type of high technology to which the President was referring. If we can maintain our partnership between public and private sectors in this work, we'll help keep America the technological leader of the world, as the President so fervently desires.

If I can provide any further information or respond to any questions regarding the fuel cell or the Fuel Cell Users Group, please don't hesitate to contact me.

Sincerely,

Lee

Lelan F. Sillin, Jr.
Chairman

LFS/lj
Enclosures

A BRIEF REVIEW OF FUEL-CELL CHARACTERISTICS FROM THE PERSPECTIVE OF NATIONAL SECURITY, SAFETY AND THE GENERAL WELFARE

Submitted by
The Fuel Cell Users Group of the Electric Utility Industry, Inc.

January 31, 1983

I. National Security: dispersed, stand-alone, fuel-cell energy systems can help diminish national vulnerability to prolonged, disruptive power outages due to accidents, terrorist attacks on electric transmission systems, or EMP (Electromagnetic Pulse) effects from nuclear detonations.

By virtue of its inherent fuel flexibility, the fuel cell can be the foundation for independent islands of energy self-sufficiency unconstrained by an aggravated reliance on long-distance transporation or a single fuel source (be it oil, gas, or coal).

In the Energy Security Act, the Congress and Administration underscored energy diversity as key to energy security. The fuel cell could be an important component in achieving this energy diversity.

II. Economic wellbeing: consistent with the President's Enterprise Zones plan, the fuel cell could serve as the nucleus for commercial activity, jobs, and redevelopment in urban, as well as non-urban, areas.

Economic revitalization could be more readily achieved through the deployment of cogenerating fuel-cell energy systems (with both electric and thermal outputs) in the inner-city neighborhoods where there might be insufficient space, services, and resources to support a conventional power plant.

This coupling of local energy availability to economic vitality is enjoying a growing level of support within many state and local jurisdictions, though it currently remains absent from the Administration's plan.

III. Adequacy of domestic supplies of fuel: Oil, gas, and even coal are of finite supply. Other fuel sources are renewable: gases from biological processes (such as sewage treatment plants or landfills), alcohols from biomaterials, methane from coal seams and shales, hydrogen from biological or electrochemcial sources, etc. All are suitable for the fuel cell.

The question of fuel availability must go beyond considerations of the proven size of the domestic resource to include considerations of the stability and reliability of the supply infrastructure for that fuel. It is not enough to know that deposits of a particular fuel abound within the continental United States if the means to bring that fuel to the consumers are inadequate or undependable.

Attachment 3

NRECA Annual Meeting 1983

RESOLUTION J-2

FROM: The Research & Technological Development Committee
APPROVED BY: Resolutions Committee

SUBJECT: Research for Growth and National Security

President Reagan, in his recent State of the Union Address, emphasized the need for greater attention to research as "the tool for growth." We commend the President for voicing strong support for research; and also we commend the Democratic party, which in its response statement, listed "Research and Development" as the number one priority for enhancing the long-term economic welfare of this nation.

We subscribe to this philosophy and urge prompt by-partisan action by the Administration and the Congress to establish a strong, well-funded federal research and development program.

Specifically, we support a well-funded, long-range commitment for Electric Energy Systems (EES) research and development and fuel cell development. These areas have national security implications as well as the potential for providing opportunities for growth and energy self sufficiency.

We therefore urge the following:

*Minimum funding of $32-million for FY-84 for Electric Energy Systems research within the Department of Energy. EES is involved with several programs of critical national importance. Among them is the study of the effects of Electro Magnetic Pulse (EMP) which in the event of strategic military weapon explosions in the atmosphere, could result in a pulse from scattering gamma rays that could create a surge 10 to 100 times faster than a lightning stroke. Such a pulse could disrupt communications and immobilize the entire electric utility industry. Other EES projects which require strong support include system technologies involving improving efficiencies and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines.

*A five year commitment, with a minimum of $33-million for FY-84, for fuel cell research and development. The potential offered by fuel cell technology for highly efficient, dispersed electric power generation (so essential to national security) is enormous. Along with the potential economic advantages, the fuel cell has other very desirable characteristics (environmentally benign, short lead time for installation, modular design, and favorable load-following capabilities) which makes it truly a "tool for growth."

Research and development on the fuel cell is focusing on producing an adaptable, resilient energy system that will handle a range of locally available fuels (carbon- or hydrogen-based gases, liquids, or solids). The fuel cell will have the capacity to switch from one fuel to another in periods of a few hours with modest associated capital costs (roughly a 5% increment).

IV. Environment, health, and safety: The fuel cell is clearly superior to existing fossil-fired options. Emissions should be significantly below any regulatory requirements; further, the fuel cell is quiet and uses little water.

Attachment 4

RESOLUTION
ON DOE PHOSPHORIC ACID FUEL CELL FUNDING

The Fuel Cell Users Group of the Electric Utility Industry, Inc.:

1. Having brought together all segments of the industry to promote commercial fuel cell applications that best meet the industry's requirements;
2. Believing that the efficiency, fuel flexibility, modularity, and environmental characteristics inherent in the fuel cell offer significant benefits to the industry, and more importantly, to its customers;
3. Recognizing that a successful development program is a prerequisite to commercialization, and that the Department of Energy and the industry share in the funding of such a program;
4. Being concerned that the proposed Department of Energy budget for fiscal year 1984 falls short of the funding necessary to sustain the development program; therefore

RESOLVES, that the Fuel Cell Users Group of the Electric Utility Industry, Inc.:

1. Believes that the fiscal year 1984 Department of Energy Fuel Cell Budget should include $22 million for development of the electric utility phosphoric acid fuel cell, and
2. Strongly urges the Congress to make these funds available.

Adopted
March 15, 1983

Robert A. Bell
President
Fuel Cell Users Group of the
Electric Utility Industry, Inc.

Senator FORD. Thank you very much, Mr. Law, and the next witness will be Carl Bagge, president, National Coal Association.

STATEMENT OF CARL E. BAGGE, PRESIDENT, NATIONAL COAL ASSOCIATION

Mr. BAGGE. I ask that my formal statement be included in the record as though read.

Senator FORD. It will be included in the record.

Mr. BAGGE. Thank you very much. It is a privilege to appear before the subcommittee and particularly before you, Senator Ford, to present the National Coal Association's views about the Federal coal research and development policies.

This subcommittee needs no reminders about coal's vital role in the American economy. Coal is America's lowest cost fuel—one-third the price of oil, and half the cost of natural gas. Today 53 percent of America's electricity, domestic, is generated by coal. By the end of this decade it will be 60 percent. Coal exports are increasingly important to the free world. Each of the past 2 years America has exported over 100 million tons of coal, adding $6 billion annually to the Nation's balance of trade.

These exports could easily double by the year 2000 and account for more than $15 billion each year to the country's trade balance.

As we look to the future, it is likely that conservation of energy in homes and commercial buildings will continue, and there is every likelihood that factors will produce more goods and more services using less energy, but despite these gains, far more energy will be required to keep the economy growing and to make certain that new workers have jobs. We believe that coal is the logical choice to serve the lion's share of these future energy demands. Its sheer abundance makes it a worthy candidate.

However, by tapping these huge reserves and by taking advantage of coal's low and stable prices, this Nation can move steadily toward the goal of energy sufficiency and energy pricing stability, both of which are essential to economic growth and development. We view Federal coal research and development policy as an important part, an important element of making certain that coal reaches its fullest potential.

We are extremely disappointed in the way that the administration has written off coal research despite all the warm rhetoric about its future.

I would like to talk about two general research areas in which the coal industry has a direct and abiding interest. First is research geared to improve the production and the mining of coal, getting coal to market in the most effective and efficient manner.

I think, Senator, we have a grasp on that. That was an issue 10 years ago—whether we could produce. Coal was discovered in 1973. Because of the oil embargo, there was the question can we produce? And we have answered that not with our rhetoric certainly, but with our ability to produce unlimited quantities of coal—120 million tons. We have 150 million tons of unutilized capacity because we responded to our Government's need to expand coal mining production. That is not the issue. That is not the research dollar needed.

Second, is research targeted to improve the direct and indirect usage of coal and also effeciently, but more importantly, consistent with environmental quality? This is the new challenge to the coal industry, unlike 10 years ago. There is also a related concern which the coal industry wishes to address. That is the research and development of new, potentially beneficial coal use technologies which are not in commercial use. My formal statement for the record contains our recommendations on those areas.

One area I would like to take if I can just a moment on, would like to cover briefly, is the development of more advanced combustion systems which are environmentally sound and economically feasible. Such systems are essential to the expanded use of coal. We really believe that the development of these systems is absolutely essential to the expanded use of coal.

Despite much progress, new, effective pollution control technology is needed, technology which could also cut the present high cost of refurbishing coal-fired powerplants. I don't have the expertise to advise the committee precisely how Federal research dollars should be allocated. My formal statement attempts to do that. It appears to us that the proposed budget, proposed fiscal year 1984 budget, for fossil fuel research does not include significant funding for research in some of these promising coal-related technologies, and I on behalf of my industry want to say here publicly that we regard this as tragic, nothing less than tragic.

In this, the coal industry supports continued research for coal preparation, flue gas cleaning, advanced fluid bed combustion, combined cycle technologies, and postwaste disposal. We support stepped-up coordination of this research among DOE, EPA, and the Bureau of Mines. I'm sorry that Senator Melcher isn't here because I had a line here for him that I think he would regard warmly. That is that nuclear power has the breeder as a dream. Coal has a comparable dream which is MHD. When I say that, I hope you will convey that line to Senator Melcher who I think hopefully it would strike a resonant chord.

Senator FORD. Senator Melcher dreams about MHD.

Mr. BAGGE. We do, too. That is our dream. The fusion people have got the breeder, Senator. Coal needs it dream, too, and I think that we have to have a comparable dream to keep us motivated for doing all the good stuff we are doing for America.

We urge the committee to consider funding these important coal technologies at the highest feasible level because they are not being funded now in the fiscal year 1984 proposed budget anywhere near the even reasonable levels where they can lead to the reduction of coal burning costs and improve environmental quality for the Nation.

I thank you very much, Mr. Chairman.

[The prepared statement of Mr. Bagge follows:]

STATEMENT
OF

CARL E. BAGGE
PRESIDENT
NATIONAL COAL ASSOCIATION

ON
DEPARTMENT OF ENERGY'S
FISCAL YEAR 1984 BUDGET PROPOSAL
FOR
ENERGY R&D PROGRAMS

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES

MAY 3, 1983

MR. CHAIRMAN, I AM CARL BAGGE, PRESIDENT OF THE NATIONAL COAL ASSOCIATION.

NCA REPRESENTS COAL PRODUCERS, SELLERS AND OTHER ORGANIZATIONS ASSOCIATED WITH THE COAL INDUSTRY.

IT'S A PRIVILEGE TO APPEAR BEFORE THIS SUBCOMMITTEE AND TO PRESENT NCA'S VIEWS ABOUT COAL RESEARCH AND DEVELOPMENT.

MR. CHAIRMAN, THIS SUBCOMMITTEE NEEDS NO REMINDERS ABOUT COAL'S VITAL ROLE IN THE AMERICAN ECONOMY. COAL IS AMERICA'S LOWEST-COST FUEL, ONE THIRD THE COST OF OIL, AND HALF THE COST OF NATURAL GAS.

TODAY, 53 PERCENT OF AMERICA'S ELECTRICITY IS GENERATED FROM COAL. BY THE END OF THE DECADE IT WILL BE NEARING 60 PERCENT. COAL EXPORTS ARE ALSO INCREASINGLY IMPORTANT. EACH OF THE PAST TWO YEARS, THE UNITED STATES EXPORTED 100 MILLION TONS OF COAL, ADDING $6 BILLION ANNUALLY TO THE NATION'S BALANCE OF TRADE.

THESE EXPORTS COULD EASILY DOUBLE BY THE YEAR 2000, AND ACCOUNT FOR MORE THAN $15 BILLION EACH YEAR TO THE COUNTRY'S TRADING BALANCE.

AS WE LOOK TO THE FUTURE, IT'S LIKELY THAT CONSERVATION OF ENERGY IN HOMES AND COMMERCIAL BUILDINGS WILL CONTINUE, AND THERE IS EVERY LIKEHOOD FACTORIES WILL PRODUCE MORE GOODS AND SERVICES USING LESS ENERGY.

But despite these gains, far more energy will be required to keep the economy growing, and to make sure new workers have jobs. We believe that coal is the logical choice to serve the lion's share of those energy demands.

Its sheer abundance makes it a worthy candidate.

However, by tapping these huge reserves, and by taking advantage of coal's low and stable costs, this nation can move steadily toward the goal of energy sufficiency and energy-pricing stability--both which are essential to economic growth and development.

We view coal research and development as an important part of making sure coal reaches its fullest potential.

In that vein, Mr. Chairman, I was privileged to deliver a paper last year to the sixth Congress of the International Committee on Coal Research, a committee which I had the privilege of getting started in 1973. Ironically, the first ICCR meeting occurred shortly before the Yom Kippur War, which, as you know, led to the Arab oil embargo.

With your permission, Mr. Chairman, I should like to insert a copy of that paper into the record, so the Committee will know of the American coal industry's keen interest in continuing coal research worldwide.

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ANY DISCUSSION OF COAL RESEARCH MUST ALSO CONSIDER THE BUDGETARY LIMITATIONS FACING THE FEDERAL GOVERNMENT.

THE COAL INDUSTRY LONG HAS SUPPORTED FISCAL RESPONSIBILITY, AND WE ARE EVER-MINDFUL THAT THE WISE ALLOCATION OF LIMITED RESOURCES CONTINUES AS A PRIORITY TODAY.

WITH THIS IN MIND, I SHOULD LIKE TO TALK ABOUT TWO GENERAL RESEARCH AREAS OF WHICH THE COAL INDUSTRY HAS A DIRECT AND ABIDING INTEREST.

FIRST, IS RESEARCH GEARED TO IMPROVE THE PRODUCTION AND MINING OF COAL--GETTING COAL TO MARKET IN THE MOST EFFECTIVE AND EFFICIENT MANNER.

SECOND, IS RESEARCH TARGETED TO IMPROVE DIRECT AND INDIRECT USE OF COAL, ALSO EFFICIENTLY, BUT MORE IMPORTANT, CONSISTENT WITH ENVIRONMENTAL QUALITY.

THERE IS ALSO A RELATED CONCERN, WHICH THE COAL INDUSTRY WISHES TO ADDRESS: THAT IS THE RESEARCH AND DEVELOPMENT OF NEW, POTENTIALLY-BENEFICIAL COAL-USE TECHNOLOGIES, WHICH ARE NOT IN COMMERCIAL USE.

COAL PRODUCTION TECHNOLOGY

THE AMERICAN COAL INDUSTRY HAS THE MOST EFFICIENT AND ADVANCED MINING SYSTEM IN ALL THE WORLD, AND WE ARE PROUD OF THIS ACHIEVEMENT.

IN THE PAST TEN YEARS, THE COAL INDUSTRY HAS BENEFITTED FROM INVESTMENTS AMOUNTING TO HUNDREDS OF MILLIONS OF DOLLARS FOR NEW MINES AND THE TRAINING OF ITS QUARTER-MILLION STRONG WORKFORCE.

IT HAS PAID OFF HANDSOMELY.

IN THE PAST FIVE YEARS, COAL PRICES AT THE MINE HAVE BEEN STABLE IN REAL TERMS, EVEN AS OIL AND GAS PRICES WENT UP.

JUST AS SIGNIFICANT, THE COAL INDUSTRY HAS INCREASED ITS PRODUCTIVITY AN AVERAGE OF EIGHT PERCENT EACH YEAR IN UNDERGROUND MINES AND FOUR PERCENT IN SURFACE MINES, SETTING THE PACE AMONG ALL AMERICAN INDUSTRIES.

THE FACT IS, THE COAL INDUSTRY HAS THE CAPACITY TO EXCEED PRESENT DELIVERIES BY AT LEAST 150 MILLION TONS A YEAR, AND WE CAN DO IT WITH THE VERY LATEST TECHNOLOGY AND TOP NOTCH SKILLS OF OUR WORKERS.

THIS DOESN'T IMPLY THAT WE CAN REST ON OUR LAURELS.

FAR FROM IT.

BUT THE PRIMARY RESPONSIBILITY FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT TO IMPROVE OUR MINING EFFICIENCY AND PRODUCTIVITY LIES OUTSIDE THE DOE BUDGET.

RESEARCH FUNDING TO PROMOTE MORE EFFICIENT AND EFFECTIVE COAL PRODUCTION IS CENTERED IN THE BUREAU OF MINES BUDGET, AND IS ALSO ENHANCED BY THE COAL INDUSTRY AND EQUIPMENT SUPPLIER'S EFFORTS.

IN SUMMARY, THE COAL INDUSTRY'S MOST URGENT CHALLENGE, NOW AND IN THE FUTURE, IS TO INCREASE COAL DEMAND, AND TO FIND THE TECHNOLOGY WHICH WILL LEAD TO MUCH GREATER COAL USE IN SUPPORT OF THE AMERICAN ECONOMY.

RESEARCH ON IMPROVED COAL USE

COAL USE IN THE FUTURE WILL DEPEND ON LARGE MEASURE ON THE PACE OF ECONOMIC GROWTH, BUT IT ALSO WILL HINGE ON THE ABILITY OF COAL TO BE USED IN AN ENVIRONMENTALLY-ACCEPTABLE MANNER.

THERE ARE A HOST OF EFFECTIVE TECHNOLOGIES WHICH REMOVE IMPURITIES AND POLLUTANTS BEFORE AND AFTER COAL COMBUSTION. BUT THESE TECHNOLOGIES ARE EXPENSIVE, AND THEY ARE DIFFICULT TO APPLY TO EXISTING POWER PLANTS AND OTHER FACILITIES.

IN COMPARISON TO PRODUCTION METHODS AND TECHNOLOGIES, THE COAL INDUSTRY DOES NOT HAVE THE RESOURCES TO CARRY OUT THE BASIC RESEARCH NEEDED TO DEVELOP SOME OF THE MORE ADVANCE POLLUTION CONTROL TECHNOLOGIES.

DEVELOPMENT OF MORE ADVANCED COMBUSTION SYSTEMS WHICH ARE ENVIRONMENTALLY-SOUND AND ECONOMICALLY-FEASIBLE ARE ESSENTIAL TO THE EXPANDED USE OF COAL.

Despite much progress, new, more effective pollution-control technology is needed--technology which also could cut the present high costs of refurbishing coal-fired power plants.

Mr. Chairman, I do not have the expertise to advise the Committee precisely how Federal research dollars should be allocated. However, it appears to us that the proposed budget for fossil-fuel research does not include significant funding for research in some of the promising coal-related technologies.

In this, the coal industry supports continued research for coal preparation, flue-gas cleaning, advanced fluid-bed combustion, combined cycle technology, and post waste disposal. In addition, we support stepped up coordination of this research among DOE, EPA and the Bureau of Mines.

We urge the Committee to consider funding these important coal technologies at the highest feasible levels. For they can lead to the reduction of coal burning costs, and also improve environmental quality.

Research Of New Technologies

Finally, let me turn to the more advanced coal uses. They fall into two categories: Mid-term and Long-term.

In the mid-Term synthetic fuels are of obvious research and development interest.

AS THE COMMITTEE MAY KNOW, THE COAL INDUSTRY HAS LOOKED WITH DISFAVOR ON A LARGE SYNFUELS PROGRAM CARRIED OUT BY THE FEDERAL GOVERNMENT. WE STILL OPPOSE SUCH A POLICY.

BUT WE BELIEVE GOVERNMENT HAS A LIMITED ROLE, PARTICULARY WITH THE PRIVATE SECTOR TO ENHANCE RESEARCH OF SYNTHETIC FUELS TECHNOLOGIES, WHICH ARE NOT READY FOR COMMERICAL OPERATION.

MR. CHAIRMAN, AS YOU ARE AWARE, INDIRECT COAL LIQUIFACTION ALREADY HAS BEEN DEMONSTRATED BY OTHER NATIONS. WE BELIEVE, HOWEVER, THAT DIRECT COAL LIQUIFACTION OFFERS FAR MORE PROMISE IN THIS COUNTRY, ALTHOUGH IT IS NOT READY FOR COMMERCIAL USE.

THE COAL INDUSTRY WOULD URGE CONTINED GOVERNMENT EFFORTS TO IMPROVE ITS PROSPECTS.

WE WOULD ALSO URGE CONTINUED SUPPORT FOR MAGNETOHYDRODYNAMICS (MHD) WHICH HOLDS PROMISE FOR THE LONG-TERM FUTURE, BUT WHICH ALSO REQUIRES A CONSISTENT AND STEADY LEVEL OF RESEARCH AND DEVELOPMENT.

LET ME AGAIN POINT OUT THAT THE COAL INDUSTRY SEEKS INCREASED GOVERNMENT INVOLVEMENT IN THE BASIC RESEARCH AND DEVELOPMENT--NOT THE COMMERICALIZATION--OF THESE TECHNOLOGIES.

FOR WE BELIEVE THAT THESE RESEARCH EFFORTS WILL PAY RICH DIVIDENDS FOR OUR COUNTRY BY ALLOWING THIS COUNTRY TO USE ITS MOST ABUNDANT AND LOWEST-COST FUEL, COAL.

IN SUMMARY, MR. CHAIRMAN, WE WANT TO SEE THIS NATION BENEFIT FROM MORE COAL USE. WE WANT TO SEE OUR MINES OPERATING AT FULL CAPACITY, AND THOUSANDS MORE MINERS ON THE JOB.

THE COAL INDUSTRY IS READY AND ABLE TO GET ON WITH THIS JOB.

BUT WE NEED THE TOOLS OF RESEARCH TO HELP MAKE SURE THAT THE JOB IS DONE.

THIS CONCLUDES MY TESTIMONY.

I WOULD BE GLAD TO ANSWER ANY QUESTIONS.

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WORLD COAL RESEARCH

The Need for A Recommitment

An Address By

Carl E. Bagge
President, National Coal Association

Before the

International Committee
For Coal Research
Sixth Congress

London, England
October 5, 1982

NATIONAL
COAL
ASSOCIATION

A decade ago this month, I had the high honor of convening this body on behalf of the American coal industry for the first time in Washington. Thus began an uncommon and historic commitment by international friends to lift coal's standing in the community of free nations. And, as we said then, to "restore our national Western heritage of coal."

As we meet for the sixth time, to share ideas, fellowship, and to reflect on the future of world coal and global coal research, we might be guided by John Galbraith's observation in his book, The Affluent Society. He said: "The enemy of conventional wisdom, is not ideas, but the march of events."

The worldwide economic recession, coupled with an oil glut and relative oil-price stability, is affecting conventional wisdom about coal's future. Uncertainty again looms on the horizon, and we in coal are no strangers to uncertainty. We coal people—the international coal community—have no reason to hang our head in despair.

Winston Churchill once said that the farther backward he looked, the farther forward he could see. Likewise, we in the world coal community need to look at our future, not in the darkness of present events, but in the light of how far we've travelled since our first gathering in Washington.

Today, I want to take you on a brief journey into the past—to look at the events and ideas surrounding the creation of the ICCR. By so doing, I believe it's possible to put the present in proper perspective, and to gain clearer view of the changes in direction that are needed for our member nations to keep moving along the long, difficult road of human progress.

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As we gathered for the first time in 1973, the Yom Kippur War raged in the Middle East. In a sense, the conflict provided an appropriate setting for the already-growing frustration about the world's failing energy condition.

Energy and political leaders alike had good reasons to fear that the worldwide economic machine would sputter as the supply of precious oil-energy was rationed at the whim of a few Mideastern landlords.

We, the world's consuming nations, were vulnerable to serious injury, because of our ever-growing oil-dependence and the clear lack of feasible national energy alternatives in the face of a worldwide energy crisis.

Even the earth's most abundant and versatile energy resource, coal, seemed to offer a "Hobson's choice." Despite its massive reserve strength, coal was in no condition then to do battle in the energy fray. Coal's vitality had been sapped by falling worker productivity and the steady inroads on coal markets by "cheap" oil and gas, a mining system of another era, and a total lack of public awareness of coal's potential. What's more, coal's potential to supply more energy for world economic growth was further compromised by increasing environmental concerns about fossil fuels in general and coal in particular.

These realities sent a clear signal to the newly organized ICCR. Coal production had to be brought into balance with expected rising energy demands. For coal to compete successfully with oil and gas, research was needed to develop new combustion technologies, to find ways of dealing with the by-products of coal burning, and more importantly, to improve productivity in the mines.

Then, there seemed to be a way to shortcut the long, laborious process of putting the world coal industry back together. The United States had just ended a decade of space achievements—a glittering example of what basic research supported by generous amounts of public funds could get done.

Converting massive amounts of coal to oil and gas would fit nicely into such a grand scheme of unified energy efforts. A large scale synfeuls industry, we believed, also could effectively cap world oil-prices—insulating consuming nations from OPEC's pricing and production decisions.

The vast amount of capital necessary for such a venture was ready for the taking. Our Congress was already considering energy research legislation. The only issue then, was whether to allocate $10 billion or $20 billion over the next five years, and what share coal could win.

But it was the political uncertainties in the Middle East that added the proper ingredient of urgency. Most political leaders, if not the public, understood the implications of rising oil prices set by a few nations.

In my speech to the first ICCR meeting, I warned that the oil price dike was about to break. World oil prices already had reached $5.75 per barrel. What's more, we were shocked when the Ambassador to Saudi Arabia, Jim Akins, predicted world oil prices of $10 per barrel by 1980 and an annual cost of $13 billion to the United States.

On October 20, four days after my keynote speech, the Organization of Arab Exporting Countries placed the United States under an oil embargo. By the end of the month, the posted price of OPEC crude had nearly doubled. By 1980, oil prices were nearly three times higher than Ambassador Akins had envisioned, and American consumers were sending $80 billion each year to pay for imported oil.

The price increase in 1973 set in motion what is perhaps the most cataclysmic energy and economic decade in history. The so-called energy crisis of the early 1970s continues even today as an oil crisis.

Yet, I'm reminded that the Chinese use two distinct characters to fashion the word crisis. One means danger. The other means opportunity. The dangers—the trials and tribulations for all the world's consuming nations—continue to dominate recent history. But from these dangers have sprung great opportunities for expanding world coal markets.

We need to take stock of what rising oil prices did for coal's fortunes—how the events of the Seventies helped to galvanize our nations into action, and elevated coal to a new, prominent and respectable position in the world commuity.

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First, the coal industry's ability to meet worldwide demand is no longer in question. Through public recognition, research and a massive infusion of capital, the world's coal mining system has been rejuvenated as never before.

The enthusiasm with which investors rushed to coal's side is testimony to a brighter future. Investors of all our free nations will act in their own economic self-interest. Just as important, the priority given to expanding coal markets by our governments at the highest level is an iron-clad endorsement of more coal use in the years to come. This was confirmed at the economic Summit meetings at Tokyo and Vienna by our economic ministers and heads of state.

The symbiosis of self-improvement and greater investment has caused a radical shift in the public's attitudes about coal. Less than ten years ago, the question was whether world coal could contribute to world energy sufficiency and price stability.

That concern was answered by the World Coal Study and the President's Commission on Coal, among others. But more to the point, the answer is clear from coal's performance—not the political rhetoric of the 70s.

Ten years ago, the world's free nations were at the mercy of OPEC, because there were too few economically-feasible energy alternatives. Now, OPEC is in trouble because of the international coal alternative.

Coal's share of the American electric utility market, now more than 53 percent, is expected to reach nearly 60 percent in a decade. Despite present market conditions, we expect growth in production of four percent each year. This is short of the seven percent once predicted, but nonetheless a sign of sound industry and market strength.

The reasons are obvious. No new oil and gas plants are planned in the United States, and nuclear power is still beset with financial and regulatory problems. What's more, since 1978 the real price of coal at the mine has remained stable or even declined. Oil and gas prices have risen.

The outlook for coal is also excellent among the OECD nations and in the Pacific Rim.

Recent reports indicate that the OECD countries will invest as much as $200 billion over the next 20 years in new coal-burning utility plants, other coal-fired facilities, and transportation to match supply with demand.

The Pacific Rim nations, especially Japan, have made a solid commitment to coal. And even though the worldwide recession has led to some reevaluation of Japan's needs, there is no indication that the Japanese are any less determined to diversify their energy base.

This doesn't imply that the battle is won. To the contrary, large gains in mining productivity are still needed, particularly in those nations where deep mining supplies the lion's share of domestic energy.

Today, better coal combustion technologies are essential to assure coal's continued competitiveness and environmental acceptance around the world.

Yet—and I want to reemphasize this crucial point—improved coal mining and production technologies today are well within our grasp. Now, the job is to build on what we've already achieved during this past decade.

Second, the events of the past several years have forced a rethinking of the coal research process, especially with synthetic fuels.

If we are honest with ourselves, we have to admit that there was too much overlapping of synfuels research—too many dollars spent for the results achieved.

This doesn't mean that synfuels production isn't important, or that the ICCR shouldn't welcome more opportunities to move ahead with synfuels research on a more selective basis. But selectivity, rather than a so-called "moon shot" effort, is the politically and economically sound alternative today. In, this, the coal industry continues to oppose a synthetic fuels program financed and carried out by the Federal Government. But we believe the government has a role in enhancing research, particularly with the private sector into synfuels technologies yet to reach commercial use.

We know now that no one technology can put a lid on world oil prices. Rather, increasing coal conversion and new coal-fired plants are already affecting OPEC's markets, as well as its pricing and production decisions.

In 1981, Sheik Yamani predicted that the world coal price would rise to the world oil price. It hasn't happened precisely because coal prices are set by worldwide competition within our industry—a plus for us and world coal consumers. And to the extent that the world coal producing nations work together to improve the mine-to-market system, coal's ability to compete with OPEC oil will continue to be enhanced.

There's another good reason why attitudes about coal research are changing. Unlike the halcyon days of the early 1970's when our nations could rely on booming economies to increase the flow of research dollars, a worldwide recession is cutting research funds to a relative trickle.

In the United States, Congress and the President are still trying to cope with record federal budget deficits, and to forge a new agenda of priorities.

Virtually every program in the federal budget is affected, including energy research. The American coal industry is resolved to live with these reductions in the national interest. Meanwhile, we are urging Congress and this Administration to bring more equity in the allocation of available research monies.

While we support the President and his efforts to turn the economy around, we are no less determined to make certain the administration lives up to its commitment to expand coal markets domestically and internationally by providing enough research dollars to help make this goal a reality.

More important, to improve American coal's competitive edge—at home and abroad—we are turning our attention to increasing competition in the coal transportation system, and to streamline existing regulations.

All our member nations are facing the same dilemma, and we must make the most of these opportunities. But there is a caveat for the ICCR: As we face a loss of world coal research funds, and as we are required to live within our national fiscal means, our coal-research capability must be safeguarded. For the richness of expertise in coal research is the world coal industry's inner strength.

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Despite unprecendented progress, despite all we've accomplished, the coal industry is facing a new kind of energy war, one which demands research soldiers of the highest ability and dedication.

I'm talking about the challenge of worldwide public acceptance of coal—the "new frontier" for coal research.

When the ICCR was born, we pledged to support research that would help to use more coal, while also protecting the environment and public health.

Initially, our attention was wisely focused on recovery efficiencies. To stimulate coal production was the appropriate challenge of the 70s. But coal production is no longer our most pressing problem. I submit, that the research of sulfur and nitrogen oxides and trace element emissions—despite the quantum leaps already made—is the foremost challenge in coal's new research frontier.

We are headed into the "twilight zone" of acid rain, the "greenhouse effect," and most probably other phenomena. These concerns will continue to weigh heavily on the minds of energy planners and political leaders as they shape future energy policy.

For example, almost overnight acid rain has emerged an an international political and scientific issue. In the United States, Congress is considering acid rain control legislation, which if passed, would cost electric consumers in a few Midwestern and Southern states more than $150 billion, while throwing thousands of miners out of work and savaging some coal markets.

This would be done, despite the obvious unanswered scientific questions about acid rain's causes and effects. And for this reason, the American Coal Industry and—I'm gratified to say—the Reagan administration are fighting this proposal.

As with past environmental issues, the coal industry again finds itself in the position of having to prove its inculpability. The calls by the coal industry for more research before launching such a damaging and costly regulatory program are seen by its critics as a delaying tactic—an attempt to hide until the acid rain debate runs its course.

This is not only dead wrong, it flies in the face of the superlative record of environmental improvement achieved by the world coal industry, the users of coal, and the United States Government over the past ten years.

We know that the acid rain issue isn't going away. What's more, we also know that acid rain isn't solely an American issue, but one which is likely to face coal producers all over the world.

As a body representing the world's leading coal producers and consumers, the ICCR has a duty to help find the causes and effects of acid rain—to stay in the lead in environmental and public health research.

For whether its acid rain, the "greenhouse effect" or some other unresolved scientific issue, the results of inaction are potentially the same: A clear and present danger to continued worldwide acceptance of coal, and to our future markets.

This, I submit to you, is not a self-serving exercise. Expanding coal markets to provide an ample supply of lower-cost energy, to fuel economic growth and development, is no longer an option. It is a world imperative, now and in the years to come.

Therefore, I ask, the ICCR on this historic occasion to recommit itself—as a decade ago—to a new, exciting and promising agenda for the decade ahead—to meet this challenge head on.

In ten short years, with the efforts of this Committee, we have helped to heal a broken and battered world-coal industry. We have emerged healthy, strong and confident and, more importantly, with a degree of public awareness we have never known before.

As we face new challenges on a new coal research frontier, we know what needs to be done. Two years ago, at our meeting in Dusseldorf, my good friend and our first chairman Erwin Anderheggen said: "It is no longer necessary to talk on the necessity of international cooperation in coal research and development. Without such cooperation, the ambitious targets set for coal production and consumption...simply cannot be reached." Let me close with a thought from one of America's greatest Presidents, Abraham Lincoln. He said:

"The dogmas of the quiet past are inadequate to the stormy present. The occasion is piled high with difficulty, and we must rise with the occasion. As our case is new, so we must think anew and act anew."

Let us in the international coal community ask not if we should proceed, but rather how. And let us get on with the unfinished job of helping all the world's people achieve a better life for themselves and for future generations—with low cost energy through coal and coal research. As we did a decade ago to the new challenge of the decade of the 80s. I ask you to rise to the challenge. Let us recommit ourselves in behalf of the world community.

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Senator FORD. It's mighty nice, Mr. Bagge, to make such an eloquent and brief statement. It is my understanding that prior to my arrival the committee decided that the witnesses could give their brief statement, their statements will be included in the record, and we would submit questions for the record. There will be some questions—I think all you have alluded to it—that I will present, and that is basically the transmittal to Congress on the deferrals, the budget for 1984, fiscal year 1984, things of that nature, and I think all of you have touched on my sentiments. I include the fluidized bed project at Shawnee in west Kentucky. Hopefully we can put that 200 megawatt on board.

It isn't a retrofit as such but basically it is, and I tend in that direction. Hopefully we can bring about the budget that gives you all the opportunity to do those things that you want to do.

I thank you for your attendance today. Today is the budget day and night and maybe budget day and tomorrow night will be budget day, so we are going to have budget coming out of our ears.

The third panel on conservation and renewable energy programs—Mr. Grant Thompson and Mr. John Casazza; Mr. Bruce Goldwater—I don't think I'll try that other one. Hildebrandt, I've got that one, but Mr. Seielstad?

Mr. Thompson is first on the list. We will hear your testimony—Conservation Foundation on behalf of the Energy Conservation Coalition, Washington, D.C.

STATEMENT OF GRANT P. THOMPSON, SENIOR ASSOCIATE, CONSERVATION FOUNDATION, ON BEHALF OF THE ENERGY CONSERVATION COALITION

Mr. THOMPSON. I am representing, as you said, the Energy Conservation Coalition which is a coalition of 16 national organizations, together with individual members, spread in each of the 50 States, representing together 16 million members who have joined together in their common interest for a more efficient America.

I have prepared testimony that I would like to, with your permission, put into the record.

Senator FORD. Your testimony in full will be included in the record, and we appreciate all of the witnesses' attitude in this respect.

Mr. THOMPSON. Thank you, sir. In the prepared testimony the Energy Conservation Coalition points out how badly energy conservation has been treated in the administration's proposed fiscal 1984 budget request.

We also point out how an additional $75 million to $125 million could be shifted into a revitalized energy conservation program, and I direct the subcommittee's attention to our detailed recommendations on programs that deserve larger support.

I would like in my summary to talk about two particular items. Those are the items of balance and the item of priority. First balance—it is easy to forget as we deal with energy, with the massive progress, that the energy equation has two sides. It has a supply side, but it also has a demand side, and they also equal one another. In the past 10 years we have seen that brought into balance by importing increasingly higher priced petroleum from the Middle

East, but we also have seen that importation drop dramatically, and that is conservation. That is advances on the demand side that have helped that.

We also tend to forget that research and development can help in the demand side as well as it can in the supply side, yet the fiscal 1984 budget puts, 96 percent of its funds are devoted to supply, while only 4 percent of the funds are devoted to conservation, and I think as we look at this energy balance, the 96 percent versus 4 percent is truly a startling figure.

Second, I would like to talk about priorities within the Department spending. Even within the overall Department of Energy funding constraints, the Energy Conservation Coalition believes that the Department has developed a priority setting methodology that by its nature biases against many worthwhile conservation R&D programs.

In effect, the Department has invented a catch-22 program. If a program should be taken on by industry, why that proves that it didn't need Government support, so that takes care of all the success stories that we have had in conservation.

On the other hand, if industry is unable to take on R&D, that proves that it was worthless because industry knows best. We believe that this catch-22 method of allocating scarce research dollars is a poor one. Instead we think that the Department needs to look at the nature of the industries where work is being done, whether they themselves have the capability to undertake energy conservation or indeed any R&D.

We submit that a priority methodology which assumes that all of the industry has the resources of a Bell Lab, of a Watson Laboratory or a Dupont Research Center is the wrong model to seek in our economy, that instead there are numerous sectors—the building sector, small commercial, small industry, homeowner, and the mom and pop shops—which simply have no ability to do conservation research and if Government lets them down, it won't be done at all.

It seems hard to believe after 10 years of success stories in conservation that Government seriously believes that it has such a small role to play in improving energy efficiency. No other government and certainly none of our competitors in the world economy are so falsely modest as to the role of government.

A theme of our testimony, sir, is the role that energy conservation R&D will play in keeping the American economy great in the next three and four decades. The Post articles over the last week have drawn our attention to the role of R&D in some of our high technology industries and the role that R&D can play in keeping us a world leader. The Energy Conservation Coalition asks to whom does the credit belong? We believe it belongs to those who put aside in the form of research knowledge that we can use in the next decade as we become more efficient.

Thank you.

[The prepared statement of Mr. Thompson follows:]

TESTIMONY
by
Grant P. Thompson
on behalf of the
ENERGY CONSERVATION COALITION
before the
Energy Research and Development Subcommittee
Committee on Energy and Natural Resources
UNITED STATES SENATE
concerning the
RESEARCH AND DEVELOPMENT BUDGET FOR ENERGY CONSERVATION
of the
UNITED STATES DEPARTMENT OF ENERGY

Good morning. My name is Grant P. Thompson. I am a Senior Associate at The Conservation Foundation, a not-for-profit research organization located in Washington, D.C. But this morning I am testifying not only on behalf of The Conservation Foundation but also on behalf of all 16 organizations representing more than sixteen million members that together form the Energy Conservation Coalition. The Coalition is an organization composed of national public interest organizations as well as individual affiliates located in all fifty states. The Coalition and its members are dedicated to a strong energy conservation program in every sector of society and at all levels of government. The member organizations forming the Energy Conservation Coalition are listed below.*

The Coalition is happy to accept the Subcommittee's invitation to testify today on the subject of the energy conservation research and development budget of the U.S. Department of Energy. Few subjects could be so timely when this country is reassessing its commitment to basic R&D as one way to recapture world leadership in technology and craftsmanship. Although some people believe that energy conservation is all low-technology, simple-minded thermostat lowering and crack sealing, nothing could be further from the truth. There is serious, scientific work to be done in conservation just as there is in nuclear physics or microchip development. And if we don't believe that the future belongs to those countries that learn to develop, market, and use energy efficiently, we need only examine the R&D priorities of our allies Japan, Sweden, and Germany, asking ourselves, "Which country's products will be more competitive when energy prices rise again?"

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* The Conservation Foundation, Environmental Action, Environmental Defense Fund, Environmental Policy Institute, Federation of American Scientists, Friends of the Earth, League of Women Voters of the United States, National Audubon Society, National Consumer Law Center, National Consumers League, Natural Resources Defense Council, National Wildlife Federation, Sierra Club, Solar Lobby, Union of Concerned Scientists, and United Methodist Church.

By this time, it seems hardly necessary anywhere but in Washington to argue that energy efficiency improvements have been a very godsend in helping extract this country from the economic and national security dilemmas in which we found ourselves following the oil price shocks of the 1970s. At the time, many Americans felt terrorized by the prospect of ever-increasing oil prices. How could we defend ourselves, short of spilling blood on the sands of the Middle East?

Yet today's news stories are full of dissension among OPEC members, falling world oil prices, and renewed world economic growth. How did the United States achieve this miracle? It wasn't new coal fields, new oil production, new dams, or new generating plants that did it. Instead, improved efficiency in our energy use demonstrated to OPEC and others that American customers could defend themselves against oil price shocks -- and do well for themselves at the same time. To be sure, the poor state of the economy cut energy use, but about half of the energy not used can be traced to energy conservation, not the recession. Nor was that energy conservation simply belt-tightening moves, to be forgotten once the memory of price shocks has dimmed: the President of Exxon has estimated that more than half of business-as-usual energy consumption never will have to be wasted again now that permanent energy conservation improvements are in place.

Proud as we may be of how well conservation helped us cope with the price shocks of the 1970s, we need to be concerned about at least two points.

First, other countries that are less timid than the United States about strong government involvement in research and development programs conserved at a far higher rate than we did over the course of the decade. Second, we need to reflect on the fact that what permitted us to react so decisively to the last set of oil shocks was partly the fruits of old wisdom -- the great ideas of the 1920s and 1930s put back into use -- and partly the fruits of new technologies and understandings made possible because of R&D conducted at the Federal level and in the private sector. But if we ignore the lessons of the last decade, there will be little defense against another disruption or even against our more efficient trading partners.

It is worth emphasizing that improved energy efficiency techniques are just like any other advance in human enterprise: they feed on wellsprings of R&D. Dry up research and development funds and eventually the nation will lose its ability to become more efficient in an increasingly competitive, constrained world economy.

To many of us, it is hard to believe that the debate concerning whether the Federal government has a role to play in energy conservation R&D can still be taken serious. The success stories growing out of relatively modest R&D investments are so stunning, the potentials so enormous, and the market structure for eliciting good R&D so weak in important sectors, that arguments made against Federal R&D programs often seem to proceed more out of rote shopworn phrases than from any very clear thinking about the opportunities, the barriers, and the payoffs involved. Three familiar examples illustrate this point:

- Fluorescent lighting accounts for about 10% of the nation's electricity consumption. Yet when manufacturers of ballasts were asked to work with the Department of Energy to find whether their product could be improved, they refused. A research contract administered by DOE's Lawrence Berkeley Laboratory led to the development of microprocessor electronic ballasts that can save between 20% and 40% of the electricity used by fluorescent lights nationwide.

- Heat pump water heaters — a configuration that permits high efficiencies as heat from the air itself is concentrated and delivered to domestic hot water -- should have been an obvious invention, combining as it does the water heater and the heat pump. Yet this product did not reach the market until after Oak Ridge National Laboratory undertook studies of feasibility and testing of performance. The market, for whatever reason, failed to encourage the R&D necessary to support this money- and energy-saving appliance, which can now be found rated in issues of Consumers Reports.

- Research funded originally by the National Science Foundation and later by FEA, ERDA, and DOE permitted the first detailed look at how existing homes actually use energy. Prior to this Federally-funded R&D, building engineers only thought they understood the building system; in many important respects they were wrong. Although their errors mattered little when they could hide their lack knowledge with oversized heating and cooling equipment, a better understanding will permit energy savings of between 30% and 60% in quite ordinary homes in the future.

Thus, Federal R&D in energy conservation has had demonstrable payoffs in the past, payoffs that the market alone failed to bring forth. The burden of proof should be on those who refuse to recognize those benefits, rather than on those of us who can point to success stories. An adequately funded program of R&D will continue to pay dividends to the nation in energy saved and in new trading opportunities created for efficient American products, if and only if the Federal government steadfastly continues to pursue and then to fund good conservation R&D programs.

The Administration has hoped that the private sector will undertake all of the R&D that the Federal government has now abandoned. In some way, the extent to which the private sector fails to fund R&D that formerly had received government support is supposed to prove that public funding was a waste of money. In other words, in a Catch-22 kind of logic, if the private sector picks up funding, it proves the government didn't need to do it, while if the private sector fails to pick up funding, it proves that the program wasn't worth doing in the first place.

The only exception permitted to this simple test of worthiness is in the case of R&D that can be labelled "long-term, high-risk, high-payoff, and generic." As applied, this test appears to favor many nuclear energy projects and almost no solar energy or conservation R&D projects. The four-part test, although couched in seemingly neutral terms, is certainly biased against R&D in energy conservation as applied, because it often shas short-term, low-risk payoffs, although still generic and of very high payoff potential. Even worse, the test may be inherently biased against energy conservation R&D, as it favors only the very expensive and exotic energy sources over the more certain mid-term conservation R&D. Ignoring the genuine needs that arise out of the special nature of energy conservation R&D, the seemingly neutral DOE four-part test effectively discriminates against many worthy R&D projects that could, if successful, save millions of dollars for Americans.

Any test used to sort out the proper role for energy R&D funding by the Federal government ought to recognize the wide variation in the nature of different energy technologies, and the resulting variation of their timing and aggregate level of payoff. Such a test ought not to be designed in a fashion to permit construction of a demonstration breeder reactor (labelled "R&D") while forbidding much needed validation of energy consumption computer models (labelled "demonstration").

Moreover, in devising an even-handed test that makes sense, the Federal government has an obligation to consider the broader implications of the energy technologies it is considering funding. What are the national security implications? How about environmental consequences of a new technology? What effects will a new technology have on employment? These are all factors that should be considered by government, even though they do not easily fit into a private company's cost/benefit calculations. The Federal government cannot afford to constrain itself to just those projects that would pass a private cost/benefit calculation: government has legitimate concerns go beyond the logic of the year-end balance sheets, concerns such as health, security, productivity, and equity.

Beyond these broadly governmental concerns that transcend the individual interests of any one citizen but go into making up a strong and healthy country, decision-makers in the Federal establishment need to look realistically at the private sector before blithely assuming that it can assume every task that some may wish to hand it. For example, not every sector of our economy is able to support R&D of any kind. The building sector -- critically important to the economy but composed largely of individual homebuilders, architects, engineers, appliance manufacturers, banks, trade unions, and investors, to name a few -- is too undercapitalized, too fragmented, and too risk-averse to sustain a research program as an industry. It stretches the imagination to suppose that home remodelers, either individually or as a group might conduct R&D. If government doesn't carry out R&D for existing homes, who will? On the other hand, other segments of industry are quite well equipped to conduct R&D. Bell Laboratories is a premier example. Another is the natural gas industry, which sustains an R&D program at the Gas Research Institute financed by a "tax" levied on shipments of gas in interstate pipelines. Likewise, the electric generating industry supports a $326 million dollar research effort at the Electric Power Research Institute. (Yet even EPRI invests only 7% of that in conservation, storage, and efficient conversion of electric energy.) Clearly, even if the telephone, the natural gas, or the electrical industries could use more R&D than they now support, there are structures for planning, funding, and conducting the R&D that exist for those industries. No such structure exists for many other industries.

It does no good to assert again and again that industry will conduct R&D if an unbiased, clear-headed look at a particular industry demonstrates that it can't or won't conduct the R&D.

In contrast to the Administration's position, the Energy Conservation Coalition believes that once government has looked at whether the fruits of particular R&D is in the national interest and at whether a particular industry might be expected to conduct an R&D program, only then is it time for government to begin ranking candidate R&D projects according to whether they can be supported with the limited amount of resources that are available. In making this final judgment, technical risks, likelihood of public acceptance, size of project against payoff and other similar ranking criteria become relevant.

Thus, the Energy Conservation Coalition urges this Subcommittee to look carefully and thoughtfully at any claims made by the Department of Energy that its R&D priorities have received the kind of ranking and sorting into rational "fund" or "no-fund" categories according to an unbiased set of standards that such programs deserve. If, as we believe to be the case, that examination reveals that slogans rather than reason lie behind the proposals the Department has made to Congress, this Subcommittee will itself have to build a sensible, defensible R&D program for the Department. Then, to insure that Congressional mandates are followed, it may be necessary to enact a detailed legislative program leaving little discretion to an unwilling Department that imperfectly understands or appreciates energy conservation R&D.

In this connection, the Subcommittee should be aware that the current program is being undermined by the failure of the Department to use FY 83 funds. I urge you to study the table on the next page which shows how slowly those funds are being obligated. We understand that the spending of funds is proceeding even more slowly this year than last.

The Energy Conservation Coalition recognizes that during a time of budget stringency, when many worthwhile programs call out for the Federal dollar, it is not enough to argue that this project or that field is especially deserving of support. Instead, the argument for support is more sustainable if it can be shown that other funding should be shifted for the sake of the program at hand. This is, we believe, the case with energy conservation. The Energy Research Advisory Board (ERAB), in a November, 1981 report on Federal Energy R&D Priorities, concluded that there was a substantial imbalance between funding devoted to supply technologies and those devoted to energy conservation. Funds for the supply technologies -- principally nuclear energy -- have risen, while those for conservation have fallen approximately 75% from last year's appropriated amount. FY 83 appropriations for nuclear fission amounted to 43% of the enetery technologies budget, conservation only 15% Yet the budget request for FY 84 proposes to give fully 61% of the money to fission and only 4% to conservation.

This strong imbalance continues to exist. The imbalance is even more surprising when one considers the clear message that the Department should have been receiving that its priorities are not widely shared. Not only have experts from outside the government criticized the balance of the Department's programs, but Congress itself has shown through its appropriations that it does not approve of DOE's priorities for energy R&D funding.

Energy Conservation Appropriations FY 83
Compared with Money Obligated Through February 28, 1983
(Dollars in Thousands)

	Total Obligational Authority	Obligations thru 2/28/83
Transportation:		
Vehicle Propulsion R&D	$36,393	$34,387
Alternative Fuels Utilization	1,649	268
Electric/Hybrid Vehicles	16,164	(768)
Advanced Materials Development	2,000	0
Transportation Utilization Programs	529	164
Capital Equipment	3	0
Total	56,738	34,051
Multi-Sector:		
Appropriate Technology	1,462	(31)
Energy Conservation Utilization	9,423	1,944
Inventors Program	2,043	522
Energy Impact Assistance	200	98
Nat'l App.Tech. Information Ctr.	0	0
Total	13,128	2,533
Buildings and Community Systems:		
Buildings Systems	14,048	1,966
Appliance Standards	1,540	1,054
Community Systems	3,845	(8)
Urban Waste	4,280	599
Technology/Cons.Products	7,936	2,039
Analysis/Technology Transfer	1,011	52
Residential Conservation Service	4,856	188
Federal Energy Management Progm	550	385
Small Business	71	(28)
Capital Equipment	15	(10)
Total	38,152	6,237
Industry:		
Waste Energy Reduction	14,545	793
Process Efficiency	10,561	2,275
Implementation and Deployment	2,414	(4)
Cogeneration	7,176	84
Capital Equipment	276	5
Total	34,972	3,153

The imbalance and the lack of attention to clear Congressional priorities suggests one place that Congress might look for additional funds for energy conservation R&D without raising the overall Energy Department budget. A relatively small amount moved from one of the supply technologies into conservation R&D could make an enormous difference in reinvigorating conservation research with only a minor impact on the donor program.

We would urge that Congress search for an additional $75 to $125 million from within the Department's own R&D funds for supply technologies in order to achieve an overall balance more appropriate to the role that energy conservation R&D can play in solving our energy problems.

In the next section of my testimony, I turn from general comments on the shape of the FY 84 budget and the philosophy that lies behind it to more specific comments on several of the categories of R&D in the budget. Obviously such comments ought to delve into an almost line-by-line dissection of the Department's proposals. I will spare the Subcommittee that, concentrating instead on the overall funding levels, providing illustrative examples where they illuminate a point.

Some Specific Comments on Budget Items

The conservation R&D budget of the Department is carried in four categories. The following table summarizes the budget authorizations for the past two years, compared with the fiscal year 1984 DOE request:

	FY 1982	FY 1983	FY 1984 DOE Request
Multi-Sector Energy Conservation	$42,193	$34,200	$13,685
Transportation Conservation	59,000	54,000	41,000
Industrial Energy Conservation	28,848	27,900	10,633
Building Energy Conservation	42,193	34,200	13,685

This table, expressed in current dollars, paints a disturbing picture. When the eroding effects of inflation over this period are included, programs are in many cases being killed as effectively by the budget process as by more direct assault. We believe that these drastic funding cuts are both unwise and unnecessary.

Multi-Sector Energy Conservation. Even by its own four-part criteria, the Department should be supporting broad funding for R&D within the multi-sector category. R&D in this category is designed to investigate conservation technologies and basic science matters that can be broadly applied throughout the economy. By its nature, this type of R&D is unlikely to be supported by any single industry because the fruits of R&D investment would be difficult or impossible to capture and turn to a profit. In order to carry out this R&D, the Department believes that $3 million is sufficient. Let us look more carefully at this number.

One component of the multi-sector program is the study of friction. If one considers the number of engines, gears, and motors used in this country, each one of which wastes a portion of its energy in the form of friction, is it not possible that a rational R&D program might use more than $3 million to support work on tribology, the science of the interactions that take place when materials move against one another? Wouldn't new materials, new configurations, or new lubricants that cut friction losses by a third or more be worth at least $3 million to this country? And can we believe that a private concern will devote the resources necessary to undertake this R&D, in view of the small individual losses that each company sustains and the difficulty of capturing the rewards of such R&D? Yet the Department believes that $3 million is enough for the entire multi-sector program of which tribology is only a part.

Likewise, when we think of the thousands and thousands of places within our economy where fuel is burned for its heat, we cannot doubt that we could find more than $3 million worth of first-rate research designed to improve our understanding of the chemistry of flame, the shaping of combustion chambers, and the transfer of heat. Yet the Department believes that $3 million is enough for the entire program of which combustion R&D is only a part.

Similarly, consider advanced materials, including better insulating products for home and industry, improved high temperature ceramics, and better heat surfaces. Would $3 million spent on research be enough if improvements put our industries in the forefront of these fields? Yet the Department believes that $3 million is enough for the entire multi-sector program of which materials research is only a part.

We believe that Congress should look at the opportunities that are available for energy savings in the multi-sector category and ask whether $3 million is enough. In answering this question, it may help to remember that other countries are spending heavily in these areas.

The Energy Conservation Coalition believes that in the multi-sector category, worthwhile R&D at a level five to six times the Department's request is easily justified.

Transportation Conservation R&D. The era of easy conservation gains for the automobile and the truck fleet are probably over. During the 1970s, the automobile companies invested their R&D dollars mainly in meeting the Federal CAFE standards. On the other hand, during the decade relatively less progress has been made in improving the overall efficiency of the truck fleet, even though most experts believe that by the end of the century overall truck fuel usage will exceed that of the automobile fleet.

The importance of the transportation sector to solving our nation's energy problems is hard to overestimate. Liquid fuels -- particularly petroleum -- remain the critical resource. Unless cars and trucks are as efficient as they can economically be, resources will continue to be wasted.

As we noted earlier in this testimony, it is important that the Federal R&D funding take into account the character of the industry. The past several years have been extremely difficult ones for the automotive industry and have been nothing short of disasterous for major truck manufacturers. At the same time, our foreign competitors, generously aided by permitted joint research and by government funding, have been making increased inroads into our domestic markets. For example, the German Auto 2000 Program supported the production by Volkswagen of its 85 mile-per-gallon car. It is instructive to stand by the Beltway and count foreign cars now and compare that count with what we remember 10 years ago. It is even more instructive to recall how rare it used to be to see a truck that was not branded International Harvester, GMC, or Mack ten years ago and to compare that figure with the number of Toyota, Mercedes, and Volvo trucks one can now count on the road.

Part of the R&D that we support is the research on how consumers actually will respond to various combinations of information, outreach, incentives, and taxes on cars of different efficiency. This is not the kind of market research that properly belongs to private industry, but rather is R&D that will go into a better understanding of how the market works in reality, so that all transportation manufacturers can make and sell a better product and so that government can craft public policies to assist in that national goal.

We believe that cooperative R&D between government and industry has a real place in transportation. But we believe that the Federal government must be willing to carry its fair share. The Department's request of $41 million is somewhat too small given the importance of this oil-consuming sector.

Industrial Energy Conservation. It is often easy to imagine that industry in this country is a homogeneous grouping. Having made that mistake, it may be natural to believe that all segments of the industrial sector are as competent at R&D as the very best. Yet Bell Labs, the Watson Laboratory, or the DuPont Research Center are as far from typical as can be imagined. Consider the R&D facilities (if you can) of the electroplating industry, that electricity-intensive industry found in industrial back alleys throughout the country at "mom-and-pop" scale. Can we seriously believe that there are "laboratories" of sheet metal fabricators, those workhorses of an industrial world with three to five workers in small buildings from Cleveland to Miami? It is simply unrealistic to believe as a matter of faith that every industrial sector is capable of supporting its own R&D. If the Federal government does not help, then no one will.

Yet in a country with a Gross National Product of more than $3 trillion, the private sector spent perhaps only $500 to $1 billion at the most on energy conservation R&D and the bulk of that was concentrated in a few large industries. By contrast, estimates of total R&D spending are in the range of $85 to $100 billion per year. Yet the Department of Energy can only think of $10 million worth of R&D to support industrial energy conservation. And DOE doesn't think that sharing conservation information among companies is worth doing.

We believe that three to five times the amount DOE has requested could easily be used in R&D by the Federal government in this sector. We recommend a careful reading of the recent ERAB report, Energy Conservation and The

Federal Government: Research, Development, and Management (January, 1983) for ideas and suggestions on many worthwhile projects and program areas that should be considered in fashioning a budget in this area.

Building Energy Conservation Research. Finally, let us turn to that most diverse sector our economy, the building sector. It would be hard to imagine an energy consuming sector that is so varied, so unable to conduct its own R&D, and yet so much in need of assistance as this one. We need only think of our own homes to see what good R&D could do for us. Does anyone here know what the most cost-effective thing he or she could do to save energy in their own home? How could we find out if we wanted to know? Are we willing to tear out walls to install insulation or would some low-cost, fire-safe insulating material yet to be developed help us without disfiguring our house inside and out? And what of our equipment: would refrigerators, water heaters, and other equipment yet to be developed help us save energy? And suppose we were to go to buy a new home? What features should we look for: what matters and what is simple sales puffery?

Who is doing the R&D in this area? Almost no one, at least in this country. Without the Federal effort we would be limited to small and fluctuating programs funded by professional societies and a very few manufacturers.

Let us take some areas that are worth funding. Consider indoor air quality. Federal R&D, now largely abandoned, was well on the way of finding ways to prevent or mitigate indoor air quality problems without wasting enormous amounts of energy through leaky buildings.

Or consider the case of lighting. The Department has requested only $100,000 to fund its lighting R&D program. Yet nationwide, lighting (both fluorescent and incandescent) consumes nearly one-fifth of all the electricity generated. That consumption is for the most part highly inefficient and frequently unnecessary. This hearing room, for example, is bright enough for all of us to be doing brain surgery or making Belgian lace, not simply discussing energy conservation R&D. Yet advances in light bulbs, in controls, in fixtures, and in building design for daylighting all could save enormous amounts of electricity for lighting purposes, with the added benefit of reducing air conditioning costs to boot. To be sure, some of this R&D should and is being conducted by light bulb makers. But even they have been prodded by Federal spending. Recall that no one was interested in improved ballasts for fluorescent lights until Lawrence Berkeley Laboratories developed them. And no manufacturer thought that screw-in high efficiency light bulbs had much of a market until DOE-funded LITEK bulbs were shown to work.

With the building industry again now on the upswing after a very long, very hard period of decline, it is more important than ever that new homes and offices reap the fruits of good R&D. The Energy Conservation Coalition recommends that funding at the level of four to six times the requested amount should be considered as a minimum.

Conclusion

In category after category, we see a lack of imagination on DOE's part, caused perhaps by ideological blinders, lack of information about the character of various sectors of our economy, or unwillingness to seize opportunities as they become available. Following several years of cut-backs across the board in many worthy Federal programs and faced with budget deficits, it may be tempting to cut out R&D programs or reduce them to the levels of last year in the hope that a little is better than nothing.

Yet we believe that such an attitude towards energy conservation is short-sighted in the extreme. Just as education is an investment in the future, just as basic science is such an investment, so R&D that will help support a great economy into the next century is an investment in our future. We are just now seeing the fruits of past R&D funded with the intent of freeing us from OPEC's grasp. Yet innovation is not a bottomless cup that continues to flow without a stream of new funding and new ideas.

It is a grand American tradition to set something aside in order to make certain that our future will be better. We did it with land grant colleges in the last century; we did it with agricultural R&D in this. We must not fail to do it with energy efficiency R&D now.

Thank you.

Senator **FORD**. Thank you very much.
Mr. Casazza.

STATEMENT OF JOHN A. CASAZZA, ON BEHALF OF THE ENERGY COMMITTEE, INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS, INC.

Mr. **CASAZZA**. Senator, I would like to enter the complete text. As you said, I will try to brief you on what we would like to say.

Senator **FORD**. Your total statement will be included in the record.

Mr. **CASAZZA**. My name is John Casazza. I am appearing here for the Energy Committee of the Institute of Electrical & Electronics Engineers. This is the world's largest engineering society. We have 230,000 members, 190,000 of whom live in the United States.

Through our testimony today I would like to present to you our institute's perspective on the nature of the current U.S. energy problem and some of the steps we feel the Federal Government should be taking to alleviate this problem.

We would like to see actions taken in two principal areas—first, to increase the efficiency of energy use—let's get more out of what we have got; and second, diversify our energy sources. Let's have more alternatives to choose from. We believe that free market forces can be constructively influenced by appropriate Government policy and action in these areas.

Now with regard to energy efficiency, we believe it has amply demonstrated that dollars spent on more effective use of what we have now in place in our society are more productive than investment in new capabilities. At least they have been in the past. Much of this opportunity to get more out of what we have was created by the sudden shifts in energy costs. However, as these easy retrofits have been implemented and continue to be implemented, significant investments in new higher efficiency technologies become necessary.

Research and engineering in these areas can have sufficient uncertainties to preclude investment by any single company yet be justified on the basis of the country as a whole.

With regard to the diversity of resources, the availability and cost of the various energy sources are changing very rapidly. The security of our country demands commitment to diversity even if it costs us something. It is a form of insurance. In the long run we believe that that diversity must be in the direction of renewable and inexhaustible supplies. Both fusion and solar technologies offer such significant long-term potential that accelerated funding to maintain the necessary scientific progress and develop the needed engineering designs should be provided.

We think the energy crisis is not over. The fundamental causes are with us and will be with us for a long time, namely, world population growth, industrialization of the Third World, and consumption of our fossil fuel resources at a rate greater than the discovery of new reserves. Despite the current world oil surplus, the United States continues to import about 4½ million barrels a day, 3 million barrels of this come from the Middle East. This continues to represent a threat to our national security. Even with the lowered OPEC price we continue to pay an oil import bill of about $50 billion a year.

As far as the efficiency of use is concerned, we have analyzed our data which is in the formal presentation, the trends in this efficiency of use of energy over the past years. The conclusion of our analysis is that the increased energy cost, especially after the dramatic price increases of the seventies, caused many opportunities to improve energy efficiency of use, and people took advantage of them. However, once these easy fixes are done, the task becomes more difficult and new technologies will be required to continue the necessary improvement.

Since 1980, the United States has experienced about a 6-quad reduction in our energy demand. A quad is 1 quadrillion. This decline results from a combination of conservation and recession in business activity. Most analysts feel in order to allow a healthy economic growth while keeping our oil imports down, U.S. energy consumption should be about 100 hundred quads by the year 2000.

The problem is that after the easy fixes have been performed, U.S. energy consumption in the year 2000 resulting from a real growth in GNP which is something I think we would all like to see of 4 percent a year would far exceed 100 quads. The market forces that we have traditionally relied on to control this growth in energy use and keep this efficiency improving we don't believe are enough.

In order to contain the overall growth of energy demand and still allow a healthy economic growth, investment in more energy-efficient technologies is mandatory. We think Congress should examine the areas for research opportunities in a number of processes, including advanced coal combustion techniques, particularly fluidized bed combustion; extra high voltage transmission, including high voltage DC transmission and switching so we can move our energy resources from where they are to where we need them; high burn up and/or lower enrichment of light water reactor fuel; and high temperature combined cycle plants or cogeneration so we get more out of each pound of coal or barrel of oil.

As far as the diversity of energy resources, we must work to diversify these, as I previously stated. In addition to all the established industries, there are important energy alternatives which can only be relied upon through a program of strong Federal support. Among these technologies for which we hope to see full Federal support are the following—solar and other renewables. The IEEE has studied solar energy as well as the other renewable technologies. It has become clear to us that solar and these other renewables offer promise for increasing our energy independence and improving the environment.

We also expect that judicious adoption of the various solar technologies will reduce our energy costs, thereby strengthening the Nation's economy. We have the capability in this country of producing all of our solar energy products and services without the need for imports, and a substantial market is almost a certainty.

For these reasons, we are convinced that solar energy will make substantial contributions. The solar energy is an infant industry with needs that compare to the needs that prevailed in the now established energy industries of the earlier days. For this reason, and to obtain the benefits of solar in a timely manner, the IEEE urges significant Federal support, including programs of, one, research and development—we need the technology; favorable regulatory policies; dissemination of information and standards development; and fiscal incentives such as tax credits.

We think special mention should also be made of the direct conversion technologies for they need special assistance to play an ever-increasing role in the long term. Photovoltaics have the promise of providing significant electric power, and very important, they will be by far the easiest form of solar energy of many other new technologies to integrate into our existing systems. It is very important that we develop technologies that we can add on as our existing systems continue to function and supply our needs.

Direct conversion technologies, however, are not now economic. The rate of progress for photovoltaics has met or exceeded DOE projections from 1977. The next major effort must be in thin film photovoltaics. Research has indicated that these thin film photovoltaics can have reasonable efficiencies, but they are going to cost too much. For this reason, no company is now risking technological obsolescence by freezing techniques and beginning a commercial venture in this area. Drastic cuts in the solar and other renewables budget, both past and proposed, are not consistent with the timely achievement of the promise of this technology.

Fusion power offers a great deal of prospect, and I think you have heard a lot of that from other witnesses. I will skip that part of my presentation.

I would like to conclude by saying that we believe it is imperative that the United States act with all due haste to increase the energy efficiency of our economy and to diversify these resources. We hope that the reduced visibility of our energy problems which have resulted from the current recession and the subsequent temporary oil surplus does not lull our country's leaders into a false sense of security. Philosophical debates as to whether the Government or the private sector should take the lead in these efforts are tantamount to arguing who should be first in line on a bucket brigade while the building burns to the ground.

This debate has been flourishing since we first suffered through the oil embargo in 1973 and will probably be going on in 1993. This morning's Washington Post and in some of our other magazines and so on I think there has been a great deal of discussion as to why we don't use our technologies in this country, why do we develop the ideas and let someone else pursue it, other nations? And I think part of the reason is we stand and argue philosophy instead of getting on with doing the job.

We hope that in 1983 the Government will realize its responsibility to make sure these steps are taken to use this technology.

Thank you.

[The prepared statement of Mr. Casazza follows:]

TESTIMONY
of
JOHN A. CASAZZA
On Behalf of the
IEEE Energy Committee
before the
Subcommittee on Energy Research and Development
of the
Senate Committee on Energy and Natural Resources
3 MAY 1983

Summary

Mr. Chairman, my name is John A. Casazza, and I am appearing before you today on behalf of the Energy Committee of the Institute of Electrical and Electronics Engineers (IEEE), of which I was chairman from 1981-1982. The IEEE is the world's largest engineering society, with over 230,000 members worldwide, 190,000 of whom live and work in the United States.

Through our testimony today, we would like to provide this Committee with our Institute's perspective on the nature of the current U.S. energy problem, and the steps we feel the Federal government should be taking to alleviate this problem. We would like to see actions taken to increase the efficiency of energy use and diversity of energy sources. We believe that free market forces can be constructively influenced by appropriate government policy and action.

With regard to energy efficency, it has been amply demonstrated that for many uses of energy, dollars spent on more effective use are more productive than investments in new capabilities. Much of this opportunity was created by the sudden shifts in the cost of energy. However, as the easy retrofits are implemented, significant investments in new higher efficiency technologies become necessary. Both research and engineering can have sufficient uncertainties to preclude rational investment by a single company, and yet be justified for the country as a whole.

With regard to the diversity of resources, the availability and cost of various energy sources have been changing so fast that the security of the U.S. demands a commitment to diversity even at some expense. In the long run that diversity must be in the direction of renewable and virtually inexhaustible supplies.

Both fusion and solar technologies offer such significant long term potential that accelerated funding required to maintain the necessary scientific progress and develop the needed engineering designs should be provided. The following detailed statement provides additional information to support and amplify these views.

The energy crisis is not over. The fundamental causes are all still present and even increasing; namely world population growth, industrialization of the "third world", and consumption of finite fossil fuel resources at a rate greater than the discovery of new reserves. The question is really when and where will new market shortages occur, and what economic dislocations and political crises will they cause.

Despite the current world oil surplus, the United States continues to import 4.5 million barrels a day, approximately 3 million from the Middle East, and an additional 1.5 million from other sources. Though this is significantly reduced from the peak reliance on the Middle East in 1978, it continues to represent a threat to our national economic security. Even with the newly lowered OPEC bench mark price, the U.S. continues to face an oil import bill that approximates $50 billion per year at present prices. Worse than the price, this supply continues to thread its way precariously through some of the most remote and geopolitically unstable regions of the world. An oil cutoff from the Middle East would directly impact on our economy. Also, the U.S. continues to maintain treaties with our western allies requiring us to share our oil supplies with them in the event of such an oil cutoff. Because many of our allies are much more dependent on Middle East oil than we are, these indirect effects would significantly increase the impact on our own economy. We urge the Congress to vigorously pursue policies aimed at reducing these risks, primarily by encouraging increases in our energy efficiency, and by diversification of the energy mix that meets the total U.S. demand. This is tantamount to saying that we are unwilling to allow market forces alone to make these choices, because collectively these forces may result in diminished diversity to an extent contrary to the security interests of the country. We firmly believe the government must set policy directions through investments in energy efficiency and alternative energy technologies which will guide market forces to accomplish these objectives in a manner which promotes healthy economic growth.

Increasing Energy Efficiency

One way of measuring a nation's energy efficiency is to measure the number of BTU's required to produce one dollar of Gross Domestic Product. The energy efficiency of the United States in 1980 is conservatively estimated to be about 30,000 BTU/$GNP (in constant 1972 dollars).

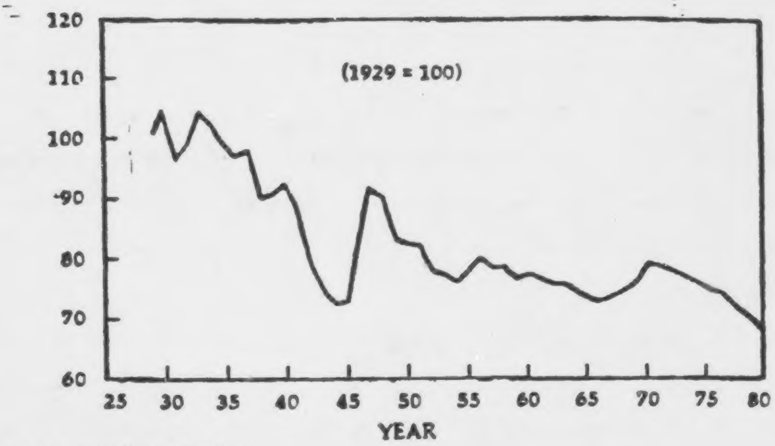
Figure 1 indicates that the U.S. has been on an improving trend, mainly the result of the introduction of new technology and the historic shift toward an increasingly large service sector in our economy with its lower energy use.

If we look at a stable period from 1949 to 1966, energy efficiency improved steadily at about one half percent per year with only a minor perturbation during the Korean war. This efficiency improvement took place even in the face of declining real prices for energy. From 1970 on, the rate of improvement has been increasing and achieved about 2% per year during the late 70's.

The conclusion of this analysis is that with increased energy costs, especially after the dramatic price increases of the 1970's, there were many opportunities to improve efficiency and people took advantage of them. However, once those easy fixes are done, the task becomes more difficult and new technologies will be required to continue the necessary improvements. For only by such continued conservation in energy use can we continue our growth without investing all of our resources in energy.

FIGURE 1

BTU/GDP (1972)



*GDP represents gross domestic product

Source: Work in Progress. Resources for the Future. Washington, D.C., July 1981.

While the chart does not show beyond 1980, since then the U.S. has experienced about a 6 quad or 8% reduction in energy demand (a quad is one quadrillion BTU's). This decline results from a combination of conservation and recession in business activity.

Most analysts agree that in order to allow for healthy economic growth while reducing our oil imports, U.S. energy consumption should be about 100 quads by the year 2000. The problem is that after the easy fixes and left only to the historical low improvement in energy efficiency per year, U.S. energy consumption in the year 2000 resulting from a real growth in GNP of 4% per year, would far exceed 100 quads. Clearly, the "market forces" which have traditionally been relied upon to improve U.S. energy efficiency is not enough.

In order to contain the overall growth in energy demand, and still allow healthy economic growth, investment in more energy efficient processes is mandatory. The Congress should examine areas of research opportunities where unproven, more efficient processes may be found. Examples of such opportunities lie in:

1. Advanced coal combustion techniques
   (Fluidized Bed Combustion)
2. Extra high Voltage Transmission including High Voltage D.C. Transmission and Switching
3. Higher burn up and/or lower enrichment of Light Water Reactor Fuel
4. High temperature combined cycle plants or cogeneration

In addition, the Congress should examine factors in the Federal laws which might be discouraging industry from adopting already available technologies for energy efficiency. Some of these technologies are power conditioning and speed control for motors, plasma arc smelting for ore reduction, use of microwave systems for surface treatment and finishing, and industrial-grade heat pumps for recovering waste product heat. We also suggest that the Congress investigate the desirability of reforming depreciation allowances for such equipment, and possibly amending environmental laws to afford an emissions credit associated with an energy reduction investment.

Finally, we should note that there is now emerging an infant conservation industry targeted toward improving our nation's energy efficiency, with needs that compare with the needs that prevailed in the now-established energy industries in earlier days. Tax credits for oil exploration and depletion allowances, and the efforts of the Atomic Energy Commission to promote nuclear power come immediately to mind. We urge the Federal Government to continue its tradition of supporting new ventures that are critical to our national well-being.

Diversify Energy Sources

In addition to increasing the energy efficiency of our economy, we must work to diversify the sources of energy on which we rely. In addition to all the established industries, there are important energy alternatives which can only be relied upon through a program of strong Federal support. It is important to be able to bring these technologies on line as soon as they become economically competitive because the increase in productivity and employment is more rapid when the the technology is new, and it thus yields greater return to society than do mature technologies. Federal support for these alternatives is therefore important not only because they will promote diversification of our energy sources, but because their early commercialization will provide opportunities for healthy economic expansion and jobs. Amongst those technologies for which we hope to see full Federal support are the following.

Solar and Other Renewables

The IEEE has studied solar energy as well as other renewable energy technologies. It has become clear that solar and other renewables offer promise for increasing energy independence and improving the environment of the United States on a permanent basis. We can also expect that judicious adoption of the various solar energy technologies will reduce our energy costs, thereby strengthening the nation's economy. Moreover, the United States has the capabilities of producing all of its solar energy products and services without need for imports, and a substantial export market is almost a certainty. For these reasons IEEE is convinced that solar energy will make substantial contributions to the national interest.

Solar energy is another infant industry with needs that compare with the needs that prevailed in the now-established energy industries in earlier days. For this reason, and to obtain the benefits of Solar in a timely manner, IEEE urges significant Federal support, including substantial programs of:

1) Research and development, including system testing, up to proof of commercial feasibility.
2) Favorable regulatory policies.
3) Information dissemination and standards development.
4) Fiscal incentives to the private sector to develop and use the solar resources. These should include tax credits, loan assistance, and selective Federal purchases.

Special mention must be made of the direct conversion technologies, for they need special assistance to play an ever-increasing role in the long term. Photovoltaics have the promise of providing significant electric power, and they will be by far the easiest form of solar energy to integrate into our existing energy systems.

Direct conversion technologies are not now economic. However, the rate of progress of photovoltaics have met or exceeded DOE projections from 1977. The next major effort must be in thin film photovoltaics. Research has demonstrated reasonable efficiencies but the current costs of the cells appear to be still too high to be commericially viable, and more importantly, no company is now risking technologic obsolescence by freezing known techniques into a commercial plan. A program of proof of commercial feasibility would accelerate the availability of competitive photovoltaic power.

Reasonable execution of such programs calls for relatively modest Federal expenditures. Nevertheless, the drastic cuts in the Solar and Other Renewables budgets, both past and proposed, are not consistent with the timely achievement of the promise of this technology. Also, inflexible restrictions that limit R&D efforts exclusively to long-term research will impede the transition from present first-generation technologies to the more advanced forms that are necessary for maximum cost effectiveness.

Fusion Power

While fusion is not a renewable technology it relies on a virtually inexhaustible source of fuel and must be considered as the main centralized concentrated future power source now contemplated.

For the budget levels which the Administration is requesting (FY 1984 - $467 million or $2 million below the FY 1983 appropriation), there is little, if any, room to perform meaningful engineering development. It is probably wasteful to pursue engineering of fusion devices without maintaining a strong science data base which explores both mainline and alternate fusion concepts. Pursuing engineering development at the cost of basic fusion science is a little like trying to build a higher pyramid by removing bricks from its base. A narrow base brings the risk of producing an unstable structure. We would not recommend trying to redirect funding from science to engineering. What we would recommend is that in addition to current funding levels to sustain a healthy basic fusion science effort, resources be allocated to begin moving the technology into the engineering development phase. Simply put, the program could very productively use a higher funding level. It is important to remember that since 1977 the magnetic fusion program budget has decreased by nearly 30%, if we mesaure it in 1977 dollars. This is even more of a loss in buying power for fusion due to its need for state-of-the-art equipment whose costs increase faster than the consumer price index. It is clear that the U.S. Fusion research program could use significant funding increases over those proposed by the Administration.

Conclusion

In conclusion, we believe it is imperative that the United States act with all due haste to increase the energy efficiency of our economy, and to diversify the sources on which we are dependent. We hope that the reduced visibility of our energy problems which has resulted from the current recession and its subsequent temporary oil surplus, does not lull our nation's leaders into a false sense of security. Philosophical debates as to whether the Government or the private sector should take the lead in these efforts are tantamount to arguing who should be first in line on a bucket brigade while the building burns to the ground. This debate has been flourishing since we first suffered from an oil embargo in 1973, and undoubtedly will be continuing in 1993. In 1983, we believe it is the responsibility of the government to ensure that the necessary steps are taken.

Senator FORD. Bruce Goldwater.

STATEMENT OF BRUCE S. GOLDWATER, GENERAL MANAGER, STIRLING ENGINE SYSTEMS DIVISION, MECHANICAL TECHNOLOGY, INC.

Mr. GOLDWATER. Senator, I am Bruce Goldwater, general manager of the Stirling Engine Systems Division of MTI. I am here today to discuss a specific program, the Stirling engineering program being conducted by my company.

I would also ask that my full testimony be submitted to the record.

Senator FORD. Your full testimony will be included in the record.

Mr. GOLDWATER. Thank you. I would like to briefly summarize that testimony.

I would like to point out first that section 302(b) of Public Law 95-238 charged DOE to initiate development of an advanced automotive propulsion system. Two basic engine cycles were selected—the gas turbine, and Stirling. The mechanical technology is the prime contractor on the Stirling program using technology from United Stirling in Sweden, a subcontractor, using American Motors General as engine system integrator.

Based on the JPL study, specific goals for the program were established—first, to achieve 30 percent improved fuel economy over existing engines, and also to achieve by 1985 legislative emission levels of 4.1 hydrocarbons, 3.4 carbon monoxide, and 0.4 N_{OX}. Two engine generations were planned to be designed and developed in order to meet the goals of the program. They are the mod I and the mod II and the strategy in the program was to transfer Stirling engine technology, at the time residing in Sweden, to the United States and apply it to the automotive application by September 1984.

Fiscal years 1981, 1982, and 1983 budget reductions have altered the level and timetable to complete the program. The mod II engine program was delayed from 1981 to 1983. To meet the legislative goals in a timely fashion, the detailed design and hardware procurement of mod II is expected to be finalized in fiscal year 1984. Therefore, our request for 1984 is an appropriation of $14 million, of which $13 million is allocated to the MTI contract. This is consistent with the recommendations of the House Science and Technology Committee.

We have established a number of program accomplishments that I think I would like to highlight for you today. Scheduled milestones and technical goals have all been met within budgetary constraints, and the high level of technology transfer from Sweden to the United States has been demonstrated.

The mod I engine has achieved its power and efficiency goals, and over 2,000 hours of development testing have been accumulated on the four engines that are within the program, 250 hours of which are on the first U.S. manufactured engine. Industry interest has been stimulated and letters have been received from General Motors and Cummins Engine Co. requesting mod I engines for their evaluation. In addition to that, we have recently received a letter from John Deere Corp., also indicating high interest in the program.

Program funds have been allocated for this purpose. The mod II design has indicated to us that all performance and emission goals have been achieved. In addition to those goals, reduction in spin rate from 7½ horsepower to less than 5 horsepower can be achieved, thereby making the engine competitive with present systems.

Elimination of the strategic material cobalt from the engine and a 30-percent reduction in chromium has been achieved, and a reduction in manufacturing cost of nearly 100 percent, making the engine competitive with the automotive engine today, is expected.

The 1984 program that we propose is to initiate the final design of the mod II engine system and to initiate the procurement of long-lead hardware items. We also are advancing the development of mod II technology to reduce manufacturing costs, lower specific weight, reduce size, increase efficiencies, lower emission levels, and increase fuel economy, and we also are projecting to continue the development of an advanced sealing system to provide the levels of reliability and durability required for industry acceptance.

In addition, we will be conducting a comprehensive engine systems program to support and maintain engines at industry company size and to establish reliability and durability levels acceptable to industry.

I would like to conclude this testimony by indicating that the original goals of Public Law 95-238 are still valid, are attainable, and are in the public interest. At present, there is no evidence that U.S. industry is in a position to assume development of advanced Stirling technology without substantial Government support. We do, however, know that Stirling engine technology is receiving increased attention and substantial government subsidies in foreign countries which may lead to a broader array of energy-efficient products, causing further domestic economic dislocation in the United States.

Therefore, during fiscal year 1984 it is proposed that we continue to develop the required technologies leading to the manufacture and test of the mod II system. We believe that successful completion of the mod II program will provide industry with the level of Stirling technology required to initiate product development.

Thank you.

[The prepared statement of Mr. Goldwater follows:]

The Automotive Stirling Engine Program
Testimony Before
Subcommittee on Energy Research and Development
Senate Energy Committee

May 3, 1983

Presented by:

Bruce Goldwater
General Manager
Stirling Engine Systems Division

Mechanical Technology
incorporated

TESTIMONY OF
MECHANICAL TECHNOLOGY INCORPORATED
LATHAM, NEW YORK
BEFORE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SENATE ENERGY COMMITTEE

Mr. Chairman, members of the Subcommittee, my name is Bruce Goldwater, and I am General Manager of the Stirling Engine Systems (SES) Division of Mechanical Technology Incorporated (MTI). MTI is a high-technology research, development, and manufacturing company located primarily in New York State, with wholly-owned subsidiaries in Michigan and California. The SES Division of MTI consists of approximately 100 people engaged in the development of both kinematic and free-piston Stirling engines for a variety of applications. MTI formed this team in response to a national need for this advanced, energy-efficient technology previously developed in Europe and Japan. MTI employs the largest group of Stirling engine specialists in the world. They are supported by unique test facilities as well.

Mr. Chairman, my company appreciates the opportunity to appear before this subcommittee. My testimony today will consist of a status report on the Automotive Stirling Engine (ASE) development program which is funded and managed by the Department of Energy under Title III of Public Law 95-238. The project management of the program has been under the NASA/Lewis Research Center. I shall also present a description of our FY '84 Program at a recommended appropriation level of 14 million dollars, a discussion of the goals of the program and indications of growing industry acceptance of the Stirling engine, together with some observations concerning the relative position of the United States, Europe and Japan in the development of this most promising technology. I have also included a set of conclusions. The figures referred to in the text are included, for your convenience, in numerical order at the end of this testimony.

In Section 302(b) of Public Law 95-238, Congress charged the Department of Energy (DOE) to initiate a program leading to the development of an advanced automotive propulsion system. Two basic engine cycles were selected for inclusion in the program: the gas turbine and Stirling. MTI is the prime contractor on the Stirling engine program.

The Stirling engine has the intrinsic theoretical capability of providing the highest efficiency and fuel economy of any engine cycle. This engine also uses continuous external combustion for its heat source, a feature that allows maximum latitude in fuel flexibility while minimizing emission levels.

The automotive Stirling engine program team consists of MTI as prime contractor, United Stirling of Sweden (USAB) as Stirling engine technologists and support group and AM General as engine system integrator. The strategy of the original program to meet the Title III objectives was to transfer Stirling engine technology residing mainly at USAB to the United States and convert it to a form applicable to the automobile. The target completion data was September 1984. The original program logic, which remains as part of the contract work statement, was to accomplish this goal through two engine generations - Mod I and Mod II.

The FY '81, '82 and '83 budget reductions have altered both the size and timetable of the original program. These reductions delayed the start of the Mod II engine program from 1981 to 1983. The FY '83 Program includes the commencement of the paper design for the Mod II engine system. In order to meet the legislated goals in a timely fashion, FY '84 will be a year in which we finalize the detail design of the Mod II engine system and procure engine hardware - hence, our request for a FY '84 appropriation of 14 million dollars. We expect 13 million dollars to be allocated to the MTI contract from these funds. This coincides with the recommendation of the House Science and Technology Committee.

NATIONAL BENEFITS

The national benefits resulting from a successful ASE Program are multifacet:

1. Jobs

   Through the introduction of Stirling technology into American products, new jobs in manufacturing, service and associated trade employment would result.

2. Technology Expansion

   A developed Stirling technology will provide American companies a wide variety of applications in addition to automotive, including heat pumps, farm machinery, electric generators, military applications, and solar power.

3. Security

   The multi-fuel capability of the Stirling engine will provide personal and national security in times of petroleum dislocation.

4. Pollution

   The Mod II engine will meet the 1985 emission standards as presented in the Clean Air Act which will contribute to the national effort to upgrade the environment. The exhaust gases of a Stirling engine are so clean that when installed in a vehicle, no catalytic converter is required.

5. Conservation

The Mod II engine will provide at least 30% better fuel economy than internal combustion engines, thereby providing significant improvement in our nation's ability to conserve energy. This improvement is strictly due to engine performance and is independent of any aerodynamic and/or downsizing changes.

6. Noise

The Stirling engine makes considerably less noise than conventional engines without any attempt at noise abatement. For example, a Stirling engine does not require a muffler when installed in a vehicle.

SUMMARY OF FY '82 ACCOMPLISHMENTS

In spite of budget uncertainties and funding cutbacks the ASE program has continued not only to meet scheduled milestones and technical goals, but also to attract the interest of industry. Neither a cost overrun nor underrun exists. The following is a summary of the major accomplishments achieved during 1982.

- We are pleased to report two automotive companies and a major engine manufacturer have shown interest in becoming involved in the evolution of the Stirling engine technology through acquisition of a Mod I engine or a Stirling engine vehicle.

- MTI was visited by two major automobile manufacturers to review the technology advances made in the ASE program and to discuss Mod I and future Mod II engine testing.

- Cummins Engine Company has submitted a written statement pointing out their desire to receive a Mod I engine in late 1983 for test and evaluation at their facility.

- Cummins Engine Company has become interested in using the Stirling engine as a bottoming cycle in their adiabatic diesel for the U.S. Army. This would not have occurred had the ASE program not advanced the state of Stirling engine technology to its current level.

- Manufacturing cost, based on the Reference Engine (Mod II) system design, was reduced to a level that is now competitive with current automotive internal combustion and diesel engines.

- The Mod I was upgraded to contain certain technologies embodied in the Mod II, thus completing the first phase of the Proof-of-Concept Mod II engine.

- The major program milestone to test and fully characterize the transient behavior of a Mod I engine was completed on schedule by September 30, 1982.

- Over 1300 engine test hours were accumulated on the four (4) Mod I engines in the program bringing the total engine test hour level to 1800. Figure 1 shows the time profile for the total accumulated test hours.

- The USA built Mod I engine, manufactured by a United States vendor base, was assembled and successfully tested for more than 235 hours.

- Critical component and technology development efforts were initiated in ceramic heat exchangers, seals, mechanical systems and controls.

- Strategic material content, a long term problem in Stirling engines, has by the introduction of high strength low cost iron-based materials, been reduced to levels that are comparable to that found in current automotive engines.

ADVANCED TECHNOLOGIES IN THE UPGRADED MOD I

During the past year the Mod I was upgraded and testing of the first engine is scheduled to begin this month - February 1983. The purpose for upgrading the Mod I was to continue developing technologies for Mod II. By using the Mod I engine important system interactions are evaluated. The major design changes made in the upgraded Mod I were:

- Part-Power Optimization: Further part-power optimization of the engine cycle is necessary to adapt it to the automotive driving cycle where high-efficiency levels are required at low engine speeds.

- Increased Operating Temperature: Increasing the engine hot section operating temperature from 720°C to 820°C improves the engine efficiency. This is due to a basic thermodynamic law which states that the higher the hot section, the higher the engine efficiency provided heat losses to the cooling water do not overcome the gain.

- Low Specific Weight: The weight of the engine was reduced by 100 pounds. The outer diameter of the engine was reduced. The hot section parts, because of part-power reoptimization, became smaller and lighter.

- Increased Efficiency: Losses were reduced in the drive system through an improved bearing design.

- Reduced use of Strategic Materials: A major change required to reduce manufacturing cost is to use low-cost materials void of strategic materials such as cobalt and chromium. No cobalt is used in the upgraded Mod I. A new iron-based material called XF-818 was used in place of cobalt-based HS31 for the cylinder and regenerator housing castings. In addition, the cobalt-based tube material N155 multimet was replaced with an iron-nickel based material called CG27.

ASE PROGRAM ACHIEVEMENTS RELATIVE TO GOALS

The Mod I was the initial phase of the ASE program during which a first generation automotive Stirling engine was designed and tested successfully. At the present time the ASE program is at a critical juncture point. Although the Mod I has been a very successful engine demonstrating specific advantages of the Stirling engine over other engine systems, it is an experimental engine and, therefore, is limited in its ability to demonstrate the full potential of low specific weight and competitive manufacturing cost. The time is appropriate to move into the final phase of the program - the Mod II. Industry has recently responded with interest and a program to provide engines for testing in their facilities is about to be initiated. The differences between the Mod I and Mod II engine systems, however, are large when the following are taken into consideration:

- Manufacturing Cost
- Specific Weight
- Simplicity
- Size
- Fuel Economy
- Automotive Configuration

Although the earlier phases of the program continued to provide information as to the potential of the Stirling engine, industry remained uncommitted until Mod I was available in hardware. Even now, only very early exploratory testing and investigation will be offered. As such, a full commitment by industry to bring the technology to market depends on the success of the Mod II phase of the program. Current financial constraints within industry preclude the investment and risk necessary to advance the technology. Major strides must be made in the areas of weight, size, complexity, and manufacturing cost. Title III legislative goals were established with this necessary step in mind and the Mod II was planned to meet these goals.

MANUFACTURING COST

The Mod I has advanced Stirling engine technologies toward those embodied in the Mod II design. Even though the manufacturing costs are quite far apart between Mod I and Mod II, the ASE program has been able to show steady progress toward important goals for not only cost but also specific weight, efficiency, fuel economy and the elimination of strategic materials.

For the past two years an intensive design effort to reduce the manufacturing cost of the Mod II has been underway. This effort has been completed. Referring to Figure 2, the cross section of the current Mod II is compared to an earlier design of March 1981. There are specific and discernible differences, all for the sake of reducing manufacturing cost or removing complexity. The drive system is a "Vee" configuration rather than "U" shaped, which reduces weight and the number of parts. The engine case is a unified single-piece cast iron block, which is cost effective. The heater is of annular construction rather than canister, which reduces cost by means of the cheaper casting process it allows. The coolers are designed for low cost extruded aluminum material rather than hundreds of separate stainless steel tubes. The main seals and piston rings reflect new simplified designs, which shorten the height of the engine. Ceramic material is used in both the preheater and regenerator, which reduces the cost in both components significantly.

Figure 3 compares the current manufacturing cost estimate of the Mod II to the Mod I and the upgraded Mod I. Estimates for the cost of I.C. and diesel engines are also indicated. The figure shows that improvements have been made in the manufacturing cost of the Mod I but, since it is an experimental engine, they are limited. The Mod II will have the necessary cost reductions to provide industry with an engine system that has an acceptable manufacturing cost.

SPECIFIC WEIGHT

Figure 4 shows the improvements made during the course of the program in lowering specific weight. The program began with the P-40 engine which contained technologies existing in Sweden at that time. The Mod I showed a marked improvement as did the upgraded version of the Mod I. However, the Mod I engine system is restricted in the extent to which specific weight can be reduced. To meet the specific weight goal required for industry acceptance the Mod II needs to be built. It will show that the annular heater head concept coupled with a Vee drive system provides an engine system weight applicable to automotive requirements.

ENGINE EFFICIENCY AND FUEL ECONOMY

Figure 5 shows the improvement made in engine system efficiency during the course of the program. Again, the Mod I and its upgraded version showed marked improvements over the baseline P-40 engine, but fall short of the required goal. The Mod II efficiency level is sufficiently high to provide industry with assurance that when the engine is applied to a vehicle system, high fuel economy will be attained.

High engine efficiency implies improved fuel economy - one of the major objectives in the Title III legislation. Figure 6 depicts the gains made in combined fuel economy during the program. In a vehicle with an EPA inertia weight class of 3000 pounds, early P-40 engines showed combined mileage levels below I.C. engines. The Mod I and the upgraded Mod I show steady improvement relative to the I.C. engine. It will take the Mod II engine, however, to meet the program goal of 30% better fuel economy than that of an I.C. engine. It is felt that a fuel economy level improvement of this magnitude will be attractive for industry to use Stirling engines eventually in automobiles.

STRATEGIC MATERIALS

One of the disadvantages with early Stirling engines was the necessity for using strategic materials in the hot section of the engine. The two major strategic materials are cobalt and chromium. Through an extensive materials development program directed by a team of metallurgists from NASA, USAB and MTI there now exists alternative materials void of cobalt which can withstand the hot environment of the engine. These new materials have been incorporated into the upgraded version of the Mod I. Figure 7 shows that in the upgraded Mod I cobalt has been completely eliminated, as it will be in the Mod II. Chromium, however, cannot be totally eliminated as it is an element contained in stainless steel, also present in I.C. engines. Ceramic material has been used in place of costly stainless steel in the heat exchangers of the Mod II, thereby reducing the amount of chromium significantly. Figure 8 shows the progress made in reducing the amount of chromium compared to an I.C. engine level.

TECHNOLOGY DEVELOPMENT

As mentioned, expensive metallic regenerator matrices have been replaced with ceramic material. Figure 9 shows a Mod I regenerator. Currently, regenerators are made from approximately 700 individual wire mesh sintered screens compressed into a stack as shown magnified on the left of the figure. Although the performance of such a regenerator is superb and contributes significantly to the high-efficiency of the engine, its cost is prohibitive. An alternative design being developed is a ceramic foam material shown magnified on the right of the figure which can be manufactured for 90% less cost and provide the same or better performance as the sintered wire mesh. This design is currently being evaluated for reliability and durability.

Ceramic material is also being considered for use in the engine preheater. The preheater is a heat exchanger which allows combustion exhaust gases to transfer heat to incoming cold air and contributes significantly to the engine's high efficiency. Currently, preheaters are metallic composed of 1100 individual plates welded together to form a complex multipass heat exchanger. With literally over three thousand welds involved, its manufacturing cost is unacceptable. Ceramic preheaters can be manufactured for 56% less cost. A comparison between a metallic and ceramic preheater is shown in Figure 10.

Four Mod I engines have tested actively throughout the year. Each engine has been tested for different purposes providing significant data toward the development of specific components, subsystems and Stirling engine technology. Without the important data received from these engine test programs development in combustion, heat exchangers, materials, controls and seals could not have progressed to the point where they are today. Engine data guide the technology development path pursued on tests in research rigs and in analytical design. Figure 11 presents powe- characteristics for the four engines tested; for the sake of clarity, only the 15 and 5 MPa* mean working gas pressure levels are included. The 15 MPa performance curve represents

* MPa: Megapascal
15 MPa = 150 Atmospheres
= 2205 psi

the maximum available power level at any given engine speed, whereas the 5 MPa curve represents an average power level required in a vehicle system. Note that the total engine-to-engine power variation was less than 10% at all power levels. In addition, the maximum power level achieved by all engines exceeded the minumum level established as the final acceptance criteria. Figure 12 shows efficiency levels attained during engine testing. Again, the data are shown for mean working gas pressures of 15 and 5 MPa. There was a greater variation in efficiency level from engine to engine; however, they did exceed the minimum level established as the final acceptance criteria. These data show engine-to-engine repeatability which is an important characteristic use by industry in establishing standard performance levels.

One Mod I engine is dedicated to the development of transient systems such as emissions and controls. To provide this capability the engine was installed in an AMC Lerma Transient Test Bed (TTB) for optimization of engine/vehicle system interfaces. A picture of the TTB is shown in Figure 13. A major program milestone to evaluate the transient characteristics of the Mod I engine by September 1982 was accomplished on schedule using the TTB. Three separate tests, each consisting of a cold start urban cycle and a highway cycle, were conducted using unleaded gasoline. Test results with projections are shown in Table 1. The combined mileage data agreed within 3% of projection which is important since the same analysis is used to project the Mod II fuel economy. Secondly, the emission levels for hydrocarbons are well below the program goal of 0.41 gm/mile. Carbon monoxide emission data met the goal of 3.4 gm/mile. The NOx level was 0.9 compared to a goal of 1.0 gm/mile. The NOx emissions will be reduced to 0.4 gm/mile on the Mod II engine system. It should be emphasized that transient testing of an engine system is not only the most cost effective, but also the most technically sound method of evaluating emission levels. The complex interactions within the combustion system and the transient response of the air and fuel control system during non-steady-state periods such as startup, accelerations and decelerations is extremely difficult to duplicate in any other set-up. As a result of this success one automotive company has expressed an interest in testing a Mod I engine installed in a vehicle.

TABLE 1
MOD I ENGINE TRANSIENT TEST DATA*

DESCRIPTION	URBAN				HIGHWAY	COMBINED
	HC gm/mi	CO gm/mi	NOx gm/mi	Mileage mpg	Mileage mpg	Mileage mpg
Test No. 1	.23	3.4	.96	19.9	31.7	23.9
Test No. 2	.29	3.3	.90	18.8	32.1	23.2
Test No. 3	.25	3.2	.84	19.2	32.4	23.5
Mean	.26	3.3	.90	19.3	32.1	23.5
PROJECTIONS	-	-	.84	19.1	30.0	22.8

* Unleaded Gasoline

TECHNOLOGY TRANSFER

Another major accomplishment during the past year was the successful assembly and test of a Mod I engine manufactured and built solely in the United States. This accomplishment demonstrated the degree to which Stirling engine technology has been transferred to the United States. The engine was tested for the first time in August 1982 and successfully passed acceptance testing with engine power and efficiency levels above the average of the other three engines in the program as reflected in Figures 11 and 12 respectively. The engine has shown excellent reliability and durability having tested for 240 hours in a five month period.

More than thirty separate vendors were established throughout the U.S.A. to support this effort. A few of the vendor types and their locations were:

Investment Casting	Oregon
Crankshafts	Michigan
Brazing Fabrication	Ohio
Machining	New York
	Connecticut
Piston - Deep Drawing	New Jersey
Ceramics	New Jersey
Tube Bending	New Hampshire
	Connecticut
Aluminum Casting	New York
Raw Material Tubing	Pennsylvania
Transducers	California
Stamping	Wisconsin

PROPOSED FY '84 PROGRAM

The program that we propose for FY '84 will include the final design of the Mod II and the procurement of long-lead-time hardware for the engine system. The timing of these actions will be in logical sequence to the Mod II component and technology development efforts currently underway and scheduled throughout FY '83 and FY '84. Our program will allow the development of a Mod II engine system with its associated advanced technology to reach a level which will contribute significantly to industry acceptance of Stirling technology. It will also make possible the attainment of legislated goals and completion of the transfer of Stirling engine technology from Europe to the United States. Specifically, the FY '84 program will include the following initiatives:

- Development of advanced technologies to reduce the manufacturing cost of the Mod II engine, namely ceramic heat exchangers, aluminum coolers and annular heater heads fabricated from low-cost iron-based materials.

- Continuation of the development of advanced sealing systems to provide the level of reliability and durability required for industry acceptance of the Mod II engine.

- A comprehensive engine test program to establish system reliability and durability levels acceptable to industry.

- The use of Mod I and upgraded Mod I engines to demonstrate critical technologies required for the Mod II to lower specific weight, reduce size, increase efficiency, lower emission levels and increase fuel economy.

- Support and maintenance of the industry test and evaluation program at industry company sites.

- Demonstration of the transfer of Stirling engine technology through component development, design and analysis of the Mod II engine system.

INDUSTRY TEST AND EVALUATION PROGRAM

A program has been planned to provide two Mod I engines to automotive and/or engine manufacturing industry companies for test and evaluation. Currently a letter has been received from Cummins Engine Company indicating their desire to receive an engine in the fourth quarter of 1983 for a 12 month test program at their own facilities. Other companies are still evaluating their resource capability to test an engine. MTI's involvement will be to procure, assemble and pre-test two engines, provide for sufficient spare hardware, and provide training to industry personnel. These training sessions will be held at MTI prior to engine delivery to company sites. In addition, MTI will provide on-site support to the industry personnel to assist them during their test program.

This program is considered a major step toward fulfilling the original purpose for the ASE program within the Title III legislation by allowing industry to become familiar with Stirling engine technology. By virtue of this program, companies will be able to evaluate the true potential of Stirling. The program will also provide a stepping stone to their evaluation of the Mod II engine system and its readiness to enter a preproduction phase.

The interest shown in this program is only one indication of growing industry acceptance. NASA conducted a survey of various companies in early 1982 to evaluate the level of awareness of Stirling engine technology and its acceptance. In all cases the companies were aware of the advances being made in the ASE program and fully supported its continuation. The technology was felt to be adaptable for various applications including automobiles and light duty vehicles. All companies expressed support for the program. They were restricted, however, in their ability to become involved due to limited resources.

There are growing indications that the Stirling engine may also lend itself to military applications either in vehicle systems or stationary electrical generation. The possibilities arise due to the Stirling's ability to use multi-fuels, its low noise level and cool exhaust gases.

FOREIGN COMPETITION

There is strong evidence that foreign governments and companies are actively pursuing the development of Stirling engine technologies. This topic was addressed at length in MTI's testimony before this subcommittee last year, including a translation of a newspaper article on Japan's "Moonlight Plan". It is known that development efforts are underway not only in Japan, but also in France, West Germany and Sweden. Three years ago Daimler-Benz acquired three P-40 engines from USAB together with an option for licensing. They have accomplished a significant amount of engine testing and currently are evaluating an engine in a light-duty van and on a dynomometer. The French government is known to be studying the use of Stirling engines for submarine applications.

NASA visited Japan in June 1982 to obtain insight into their government/industry/university cooperative research method and to determine the objectives, status and plans for Stirling research. Visits were made to the University of Tokyo, Nissan Motor Company, Aisin Seiki Company (Toyota Group), Yanmar Diesel Engine Company, Diahutsu Motor Company and Diahatsu Diesel Manufacturing Company. NASA found that a Stirling development project has started with funding for approximately 40 million dollars (between 1982 and 1988). There will be several companies involved aimed at the development of 3 Kw heat pumps and 30 Kw generator sets. It was found that considerable computer code analysis is underway at the University. Ceramic development was also being pursued. Marine Stirling research was conducted at Diahatsu during years 1976 to 1981. Conclusions from this trip were that the government/industry/university relationships in technology development appear to depend heavily on carefully establishing a strong initial constituency, a stable long-term government commitment, a strong university review system and a cooperative attitude among companies. Finally, it was concluded that there is a serious long-term government/industry commitment to developing Stirling technology characterized by a new six year $40M government program, major company commitments, and automotive company interest. It was felt that their current technology level is behind the ASE program and that there is a strong awareness of our program.

CONCLUSION

In conclusion, Mr. Chairman, I would like to summarize by stating the following:

1. The ASE program is a successful example of the type of program that should be supported by the Federal Government to address major national needs.
2. The original goals of Title III of Public Law 95-238 are still valid and in the public's interest.
3. During FY '84 the required technologies will have been developed to the point where a Mod II engine system could be built and tested to meet these goals, thereby providing a technology level that can be assumed by the U.S. industry.
4. There is no evidence that U.S. industry is in a position to pursue development of Stirling technology without substantial Government support. It is necessary for this program to provide a Mod II engine system in hardware which the industry can assume without extensive development costs.
5. Stirling engine technology is receiving increased attention and support by foreign governments and companies which may lead to a broad array of energy-efficient products that could cause further domestic economic dislocation in the United States.

Thank you, Mr. Chairman, for this opportunity of appearing before this important subcommittee. I would be pleased to answer any questions which you or other members may have at this time.

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

MOD I ENGINE TEST HOURS

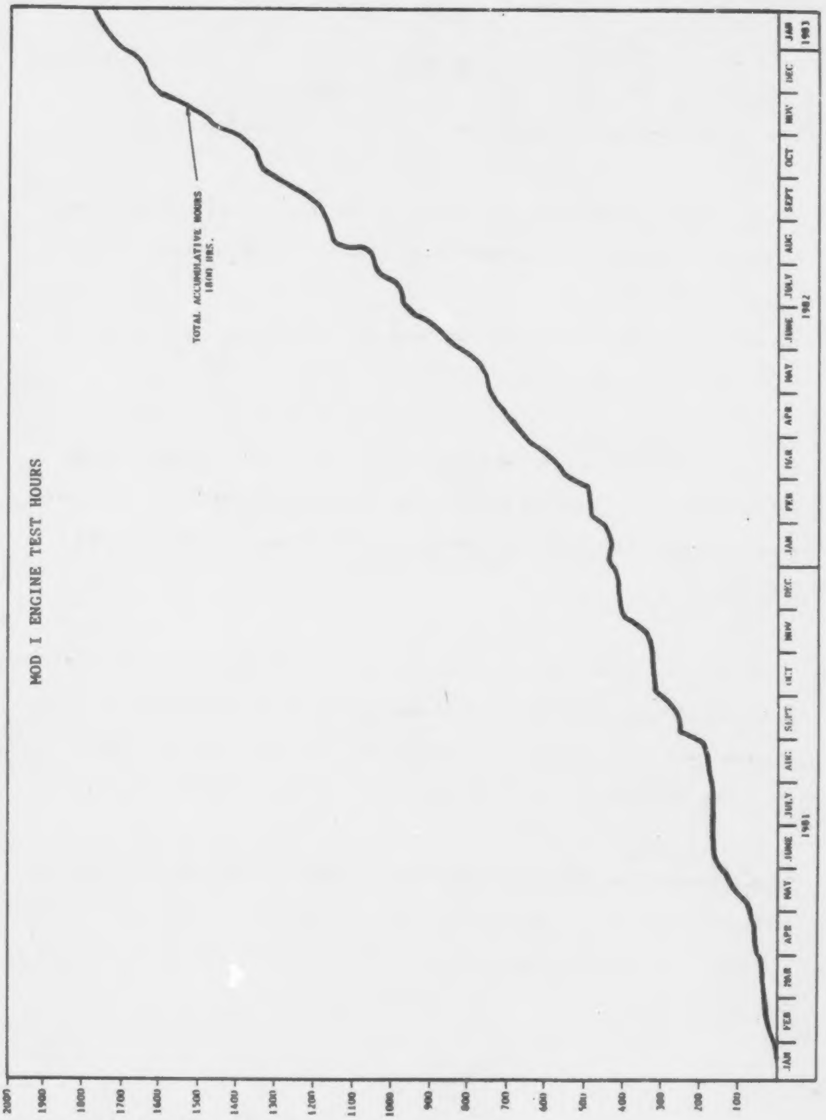


FIGURE 1

AUTOMOTIVE STIRLINE ENGINE DEVELOPMENT PROGRAM

MOD II COST REDUCTIONS

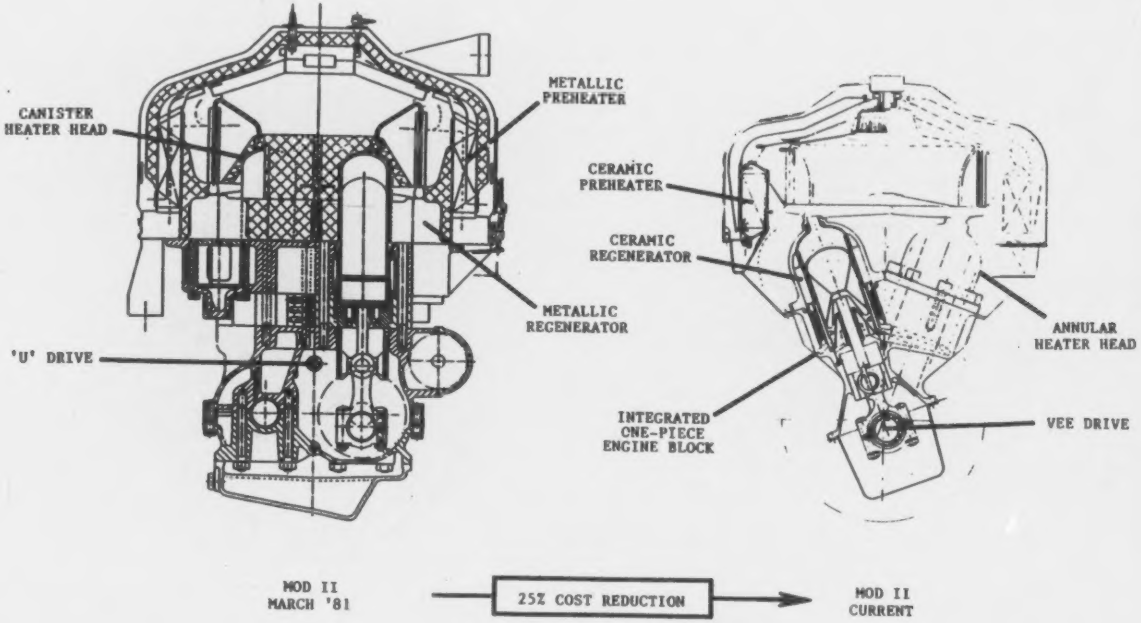

CANISTER HEATER HEAD
'U' DRIVE
METALLIC PREHEATER
METALLIC REGENERATOR
CERAMIC PREHEATER
CERAMIC REGENERATOR
INTEGRATED ONE-PIECE ENGINE BLOCK
ANNULAR HEATER HEAD
VEE DRIVE
MOD II MARCH '81
25% COST REDUCTION
MOD II CURRENT

FIGURE 2

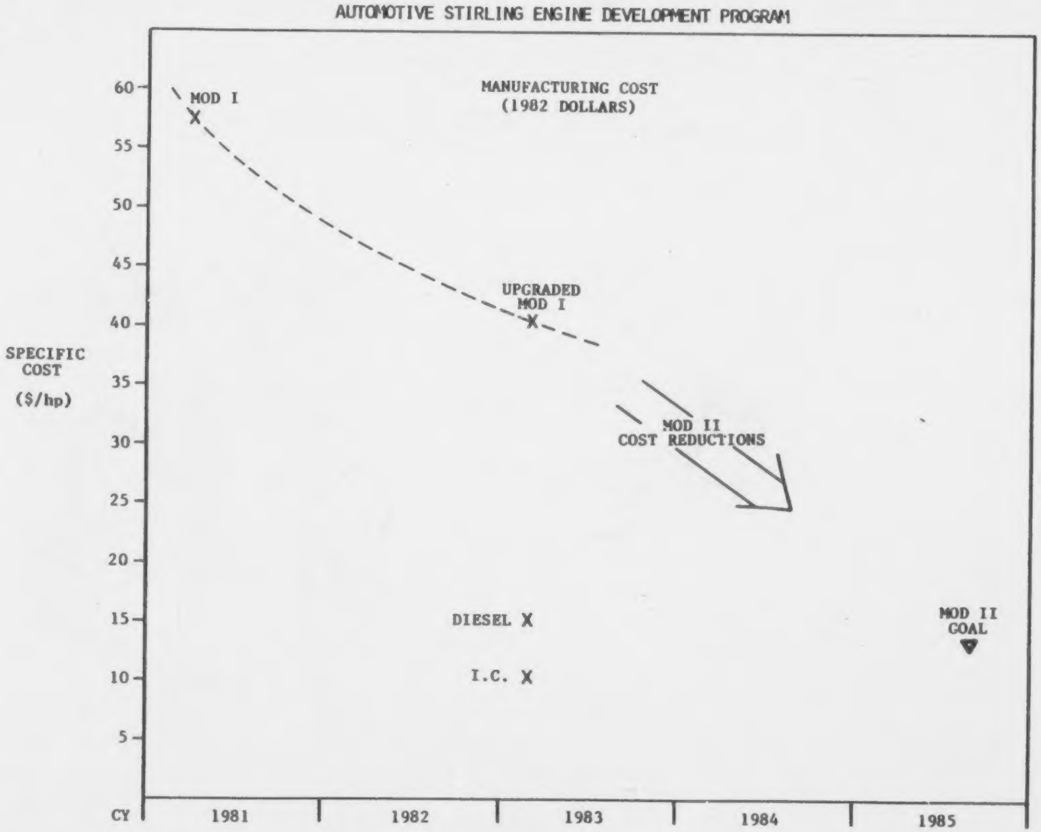

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM
MANUFACTURING COST (1982 DOLLARS)
SPECIFIC COST ($/hp)
60
55
50
45
40
35
30
25
20
15
10
5
CY
1981
1982
1983
1984
1985
MOD I
UPGRADED MOD I
MOD II COST REDUCTIONS
DIESEL
I.C.
MOD II GOAL

FIGURE 3

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

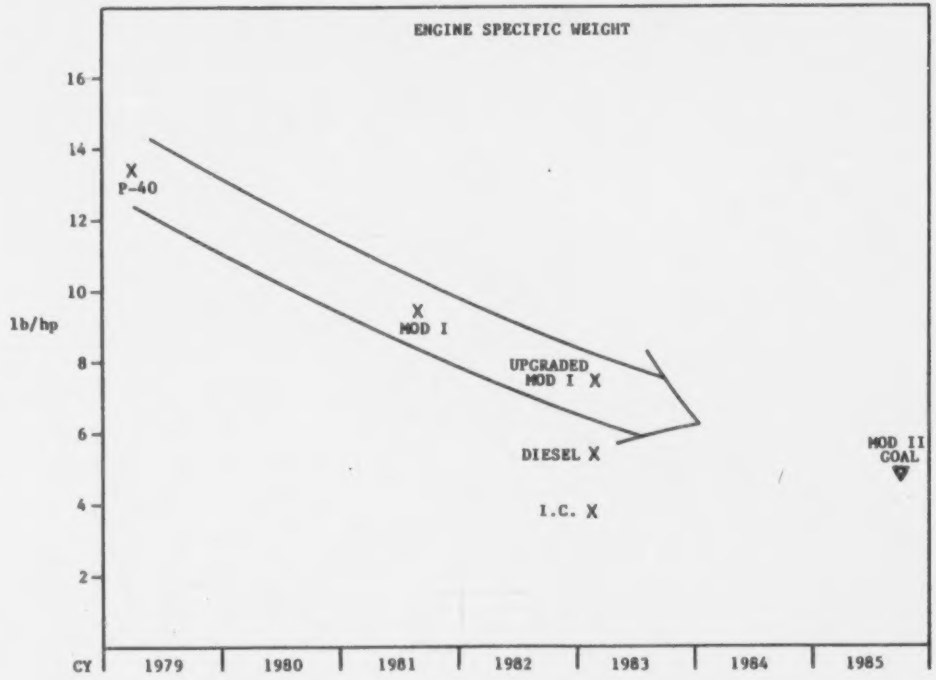


FIGURE 4

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

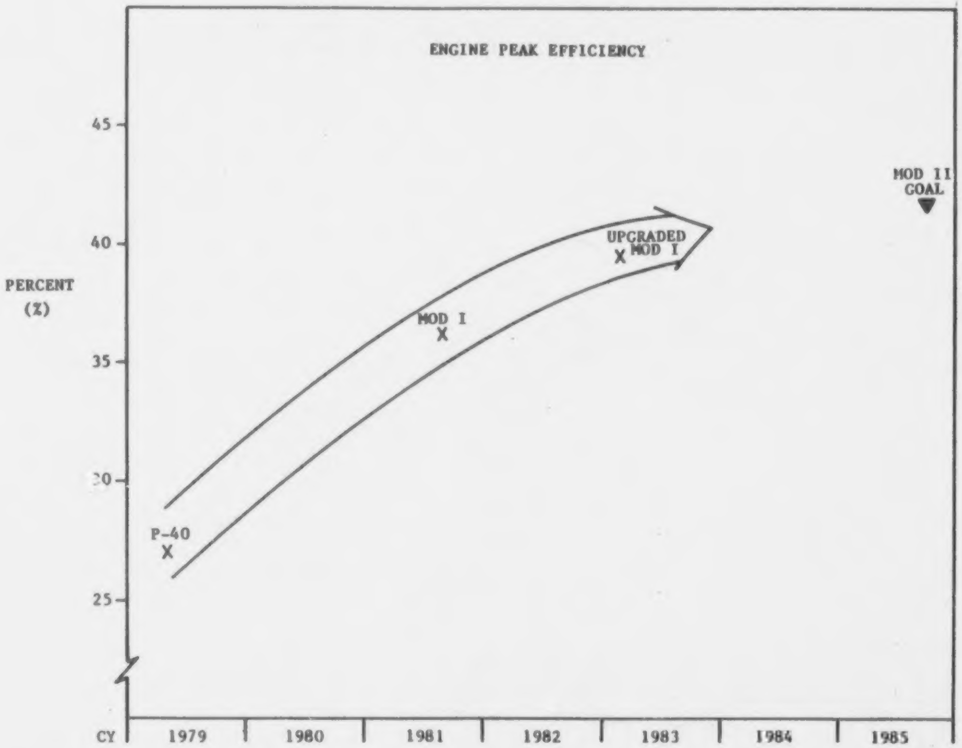


FIGURE 5

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

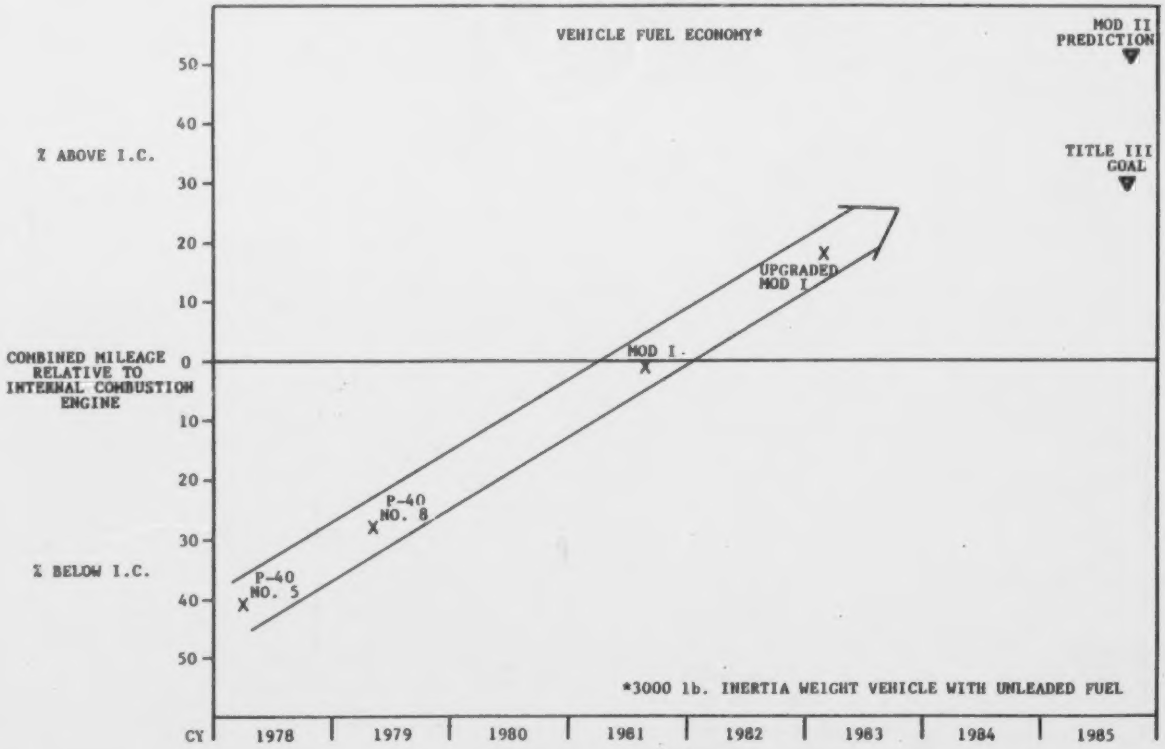


FIGURE 6

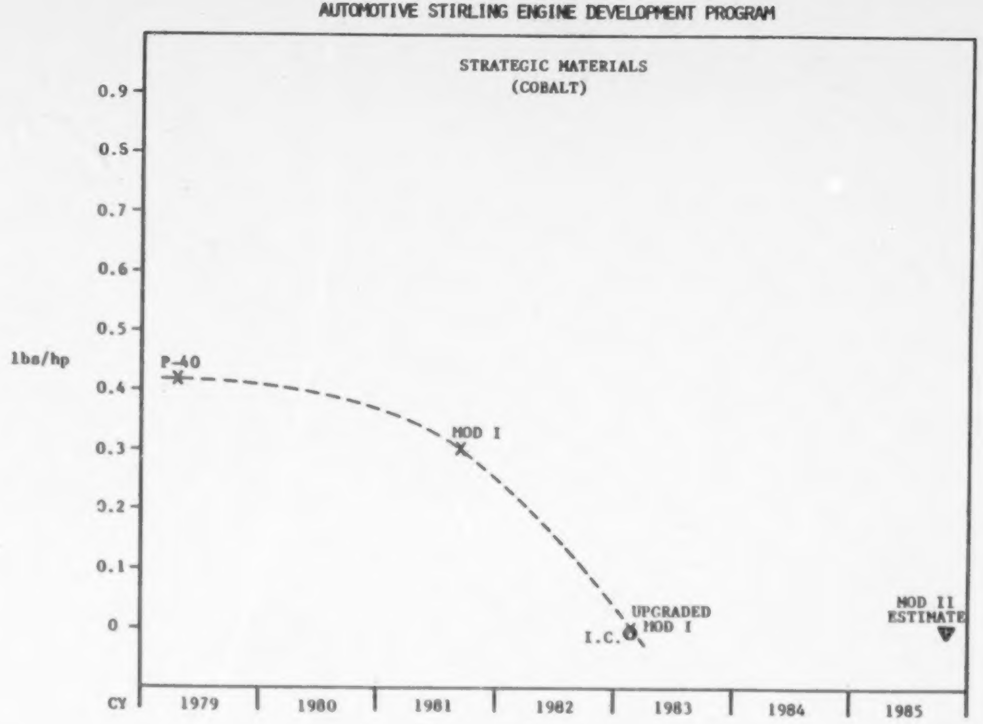
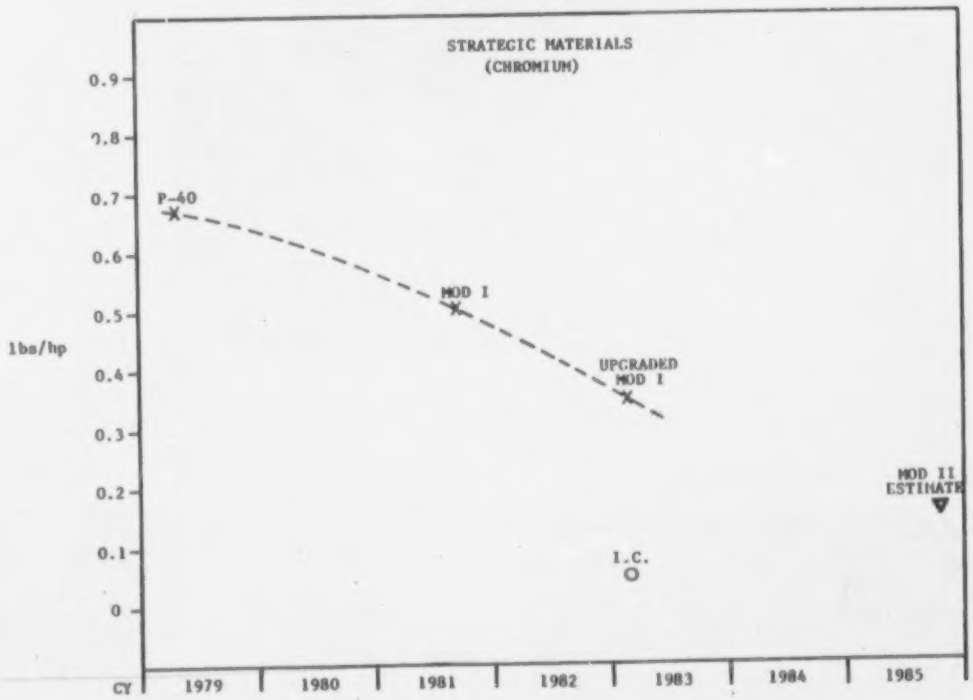

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM
STRATEGIC MATERIALS
(COBALT)
lbs/hp
0.9
0.5
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CY
1979
1980
1981
1982
1983
1984
1985
P-40
MOD I
I.C.
UPGRADED
MOD I
MOD II
ESTIMATE

FIGURE 7



AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

FIGURE 8

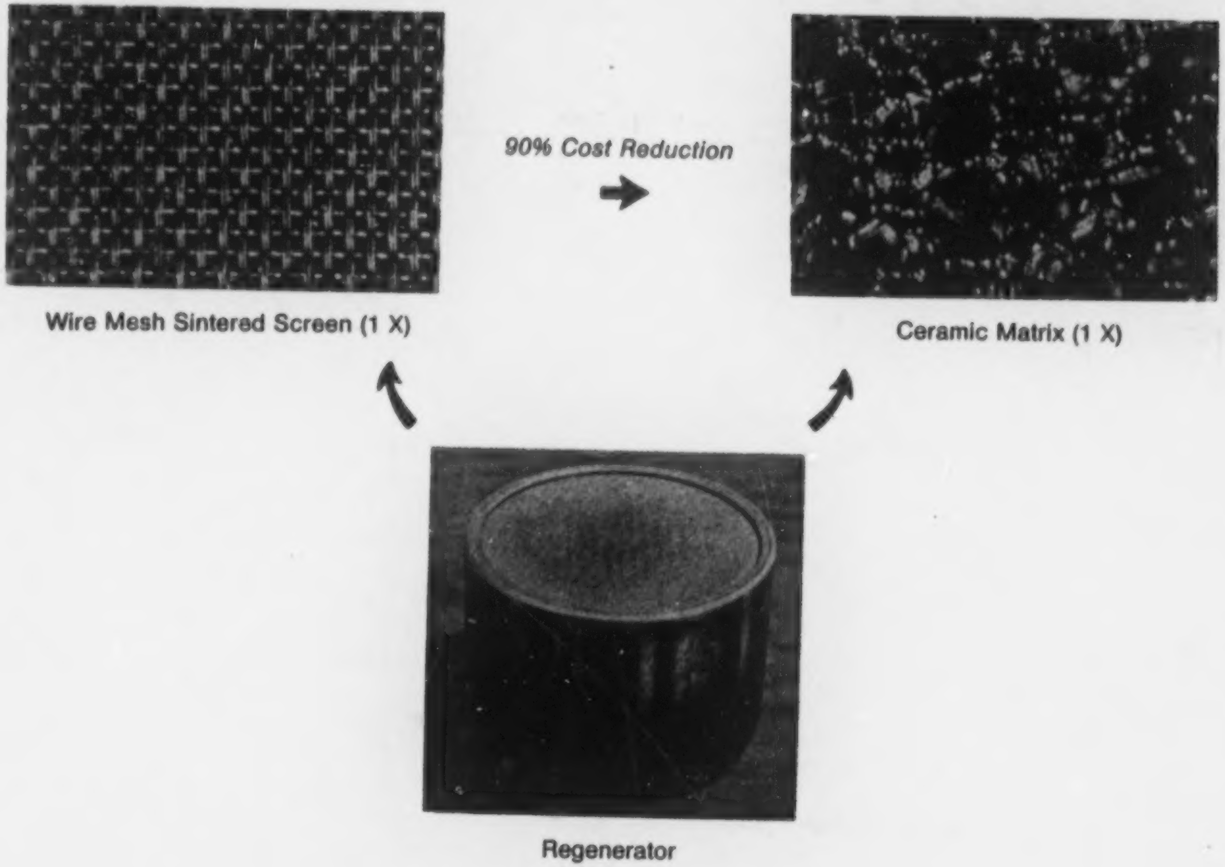

90% Cost Reduction
Wire Mesh Sintered Screen (1 X)
Ceramic Matrix (1 X)
Regenerator

Fig. 9 Comparison of Regenerator Matrix Material

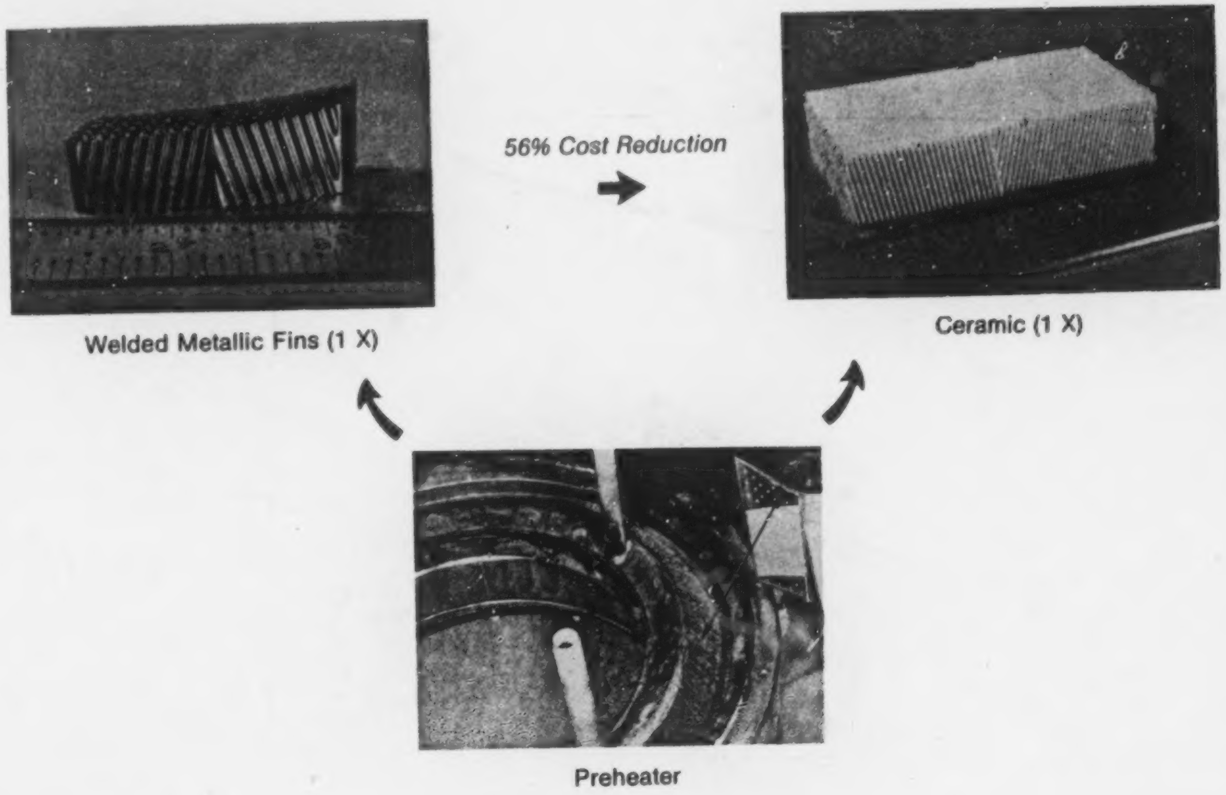

Welded Metallic Fins (1 X)
56% Cost Reduction
Ceramic (1 X)
Preheater

Fig. 10 Comparison of Preheater Material

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

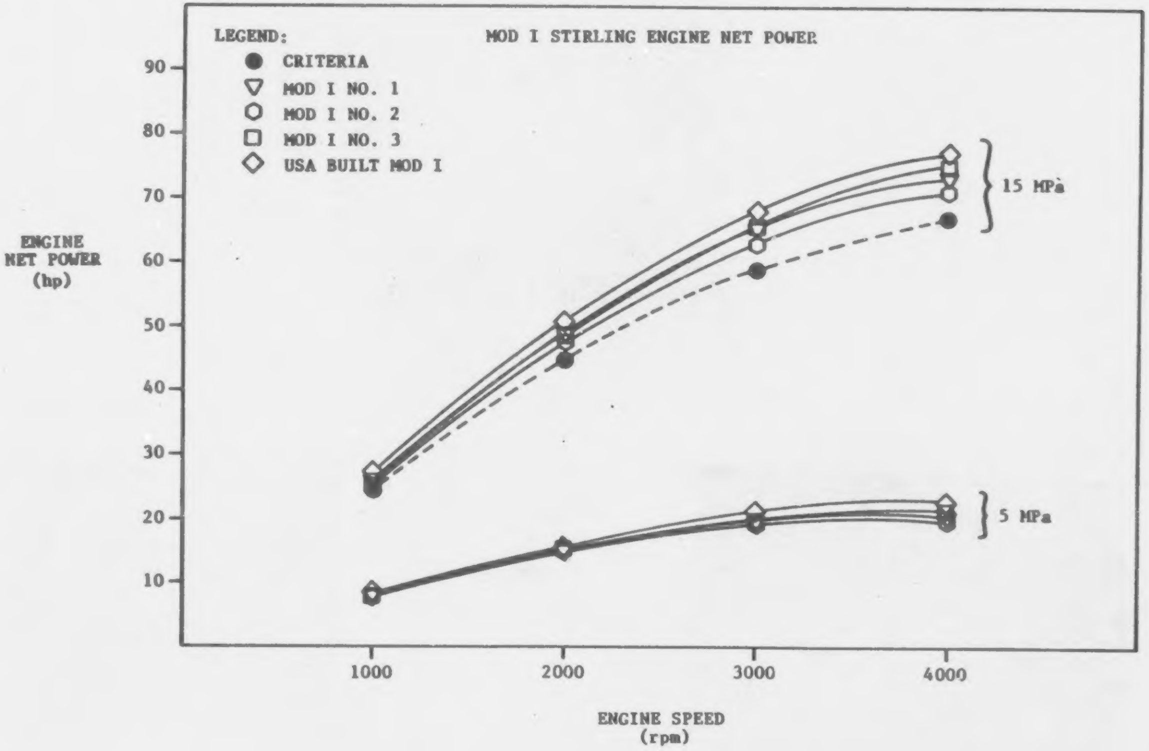


FIGURE 11

AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM

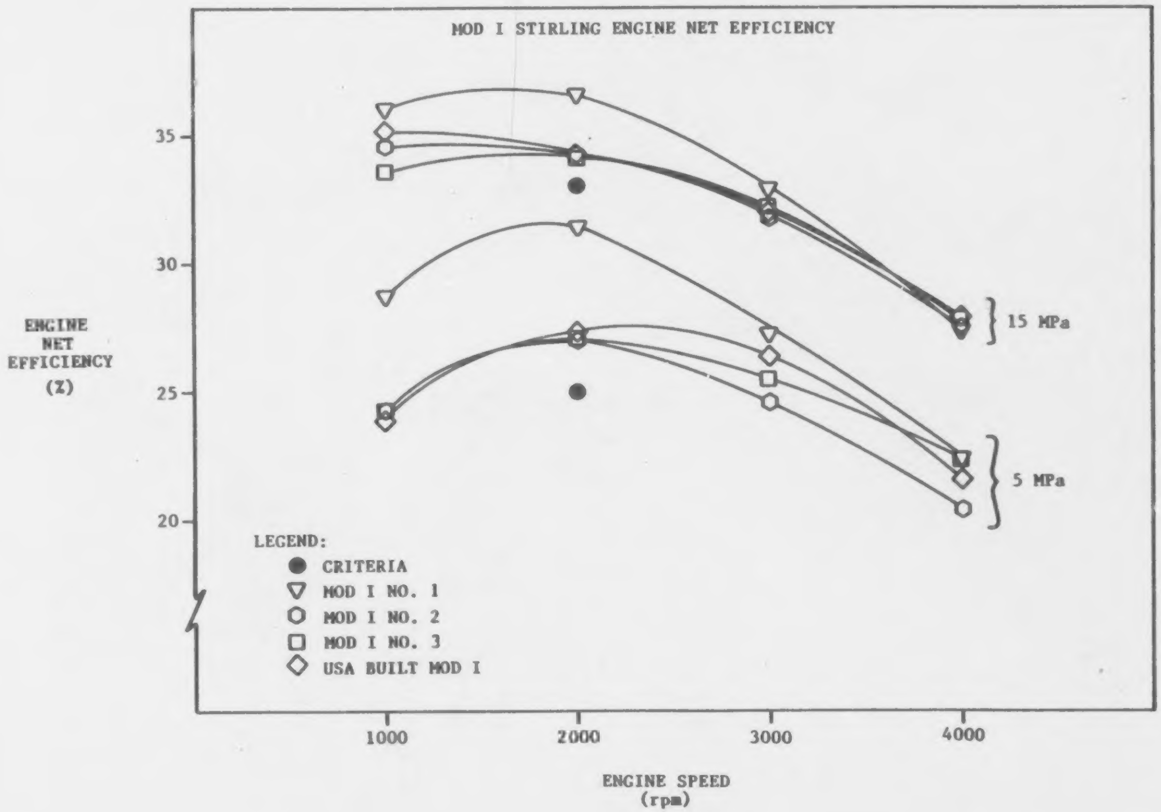


FIGURE 12

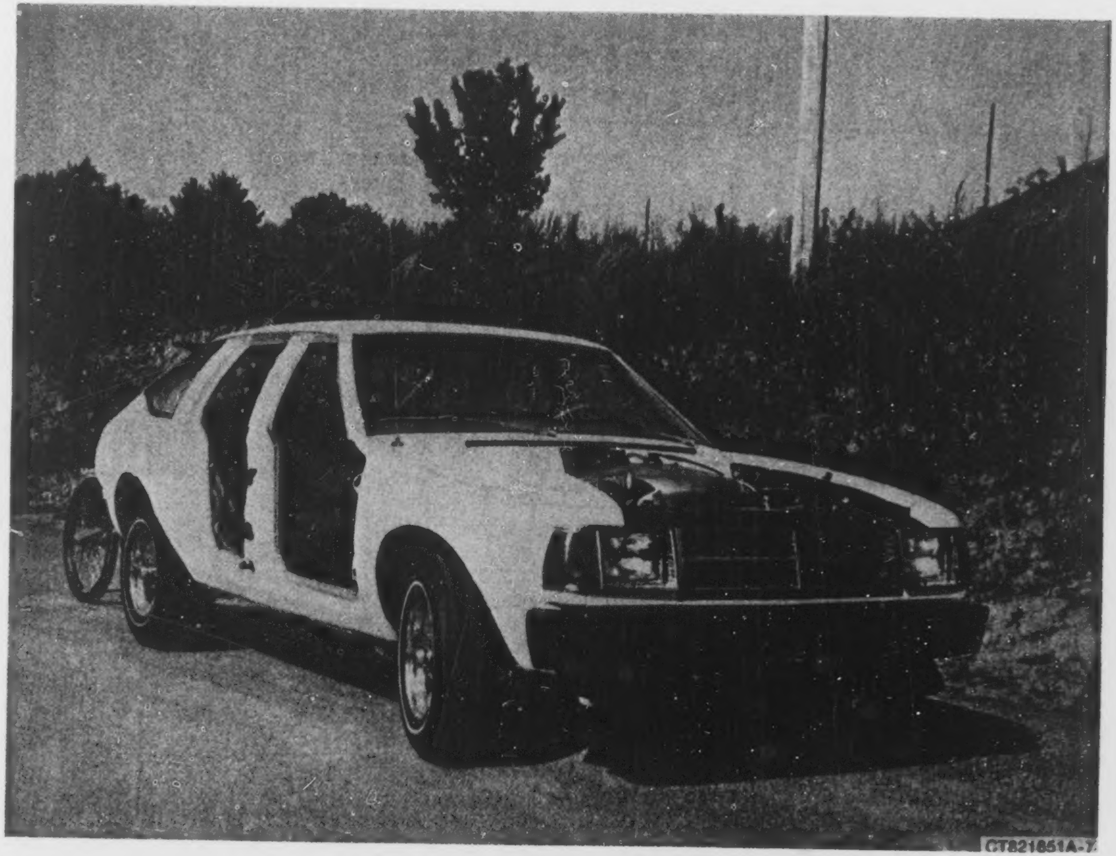

CT821651A-7

Fig. 13 Mod I Engine Installation in Transient Test Bed

Senator **Warner** [presiding]. Thank you very much. I certainly want to offer my apology to all those who tried today to make this hearing effective, and I have been chairing hearings since 8:30 this morning, defense committees, and forgive us for coming in. As you can see, we have a very strong bipartisan working relationship with our colleagues on the other side, and together I hope we have enabled you to express and place on the record your views on this very important subject, and I am glad to have the opportunity to remain now for our final two witnesses.

I understand that would be Mr. Alvin Hildebrandt, chairman of the Committee on Environment and Energy, National Association of State Universities and Land Grant Colleges.

STATEMENT OF DR ALVIN F. HILDEBRANDT, CHAIRMAN, COMMITTEE ON ENVIRONMENT AND ENERGY, NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND GRANT COLLEGES

Dr. **Hildebrandt**. Senator, I am Prof. Alvin Hildebrandt, director of the Energy Laboratory at the University of Houston, and it is a privilege and a pleasure to present to you the view from the National Association of State Universities and Land Grant Colleges.

I have submitted a full text for the record, but in the interest of time I will briefly summarize our position.

The university has viewed a large, dramatic reduction in energy research and development programs in the budget proposed to you for fiscal 1984 in the crucial areas of fossil energy, conservation, solar, and other renewables. The proposed budget reductions total more than $600 million. These areas are among the most crucial to the future energy needs of the country, and they are also the most critical with respect to requirements for advanced training of energy experts needed by industry, Government, and universities.

The magnitude of the reductions, more than 60 percent, are particularly devastating to the continuity of research development and educational programs.

Characteristics of the three forms of energy vary greatly from State to State and region to region. The same coal burned in one type of powerplant in one part of the country must be handled differently in another part of the country where the wind and environmental conditions vary by substantial amounts. State and regional differences are even more pronounced in conservation, solar, and other renewable energy systems. Conservation in the North primarily relates to cutting heat losses in buildings in the winter. In the South it is primarily related to loss of cooling and air-conditioning costs. Universities are a particularly valuable resource in the United States for adapting general research to specific State and regional needs.

The proposed reductions in the budget in these areas are especially detrimental to the future of university research and to the relationships of these universities to the industry and culture in the locations where they operate. We are suffering the increasing obsolescence of instrumentation and decline in technological preeminence. Further, we need to address both short-term and long-range energy impacts of fossil and renewable energies. Because these resources are locally oriented, investment in development runs a higher than normal risk for research. Output is not generally applicable nationwide.

The size of the system, for example, in uniformity of the market for alternative energy sources varies in different geographical areas. The very complexity of regional needs means that Federal support for research and development in these areas is more important, not less important. Energy savings anywhere in the United States mean more net energy available for the Nation.

Thus we recommend to you that these enormous and devastating budget cuts be reconsidered and reversed. Many of these energy systems are labor-intensive. This means they will contribute immediately and in the long range to reduction in unemployment, particularly among less well-trained workers, and we urge you to reconsider national priorities in energy research and development and move programs and funding into universities. There Federal money will be multiplied by State and regional resources, and the powerful and important byproduct of greater increased manpower development will contribute now and in the future to the country's energy independence and achievement.

For each dollar of energy research and development placed in the universities, about 25 cents is used to support students who contribute to the needs of the country for the next 40 or more years after their training. In contrast, every dollar placed in a national lab pays less than 1 cent in support of students who contribute to the future energy manpower needs of the country. University energy research and development is not only lower in cost and more efficient, it contributes the important additional element of enhancing and enlarging the human resource achievements.

Also universities can readily transfer technology directly into industry through joint research programs.

Energy research and development in the United States today is primarily planned as a top-down process. This results from the legacy of the Atomic Energy Commission. Changing times, especially in nonnuclear areas, now indicate we should have an energy research and development program that is bottoms up based on regional circumstances. This means that local and regional needs should be organized, formulated, and coordinated at the national level so that energy research and development programs served the whole country in an intimate network that has the support and understanding of all the people.

A model of the past is the agricultural experiment stations. We are sure that any such program will indicate that a dramatic shift of resources into programs that support conservation, coal, synfuels, energy utilization, and the development and utilization of renewable energy systems will be an advantage both now and in the next century when these systems will contribute most to the energies of this country.

I thank you for the opportunity to submit this testimony.

[The prepared statement of Dr. Hildebrandt follows:]

TESTIMONY OF NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES
COMMITTEE ON ENVIRONMENT AND ENERGY
ENERGY R&D PRIORITIES SUBCOMMITTEE

Subject: Proposed Funding Increases for Research and Development in the Areas of Conservation, Fossil, Solar and Renewable Energy and the Development of Trained Experts in Universities.

Submitted to:

Senate Subcommittee on Energy Research and Development

Submitted by:

Alvin F. Hildebrandt
Director of the Energy Laboratory
University of Houston

Senator Domenici and Members of the Committee, it is a privilege and a pleasure to present to you a view of the National Association of State Universities and Land Grant Colleges. Universities have viewed with alarm the dramatic reductions in energy research and development program budgets proposed to you for fiscal 1984. In the crucial areas of fossil energy, conservation, solar and other renewables, proposed budget reductions total more than $600 million. The Department of Energy R&D past authority and the 1984 Administration proposed budgets are shown in the following chart:

Department of Energy - R&D

	Budget Authority		
	1982	1983	1984
Conservation	444	410	101
Fossil	567	311	138
Solar and Other Renewables	343	253	102

These areas are among the most crucial to the future energy needs of the country and are also the most critical with respect to requirements for advanced training of energy experts needed by industry, government, and the universities. Development in these areas can have a very positive employment effect, both locally and nationally. The magnitude of the reductions--more than 60 percent--are particularly devastating to the continuity of research development and educational programs.

Part of the rationale for the administration budget cuts in these areas lies with the supposition that industry would continue to fund the research and development work necessary to move energy technologies to the marketplace. Such rationale was based, in part, on the faulty assumption that existing technologies had progressed to the point of economic viability. Furthermore, these reductions apparently do not recognize the potential effects that changing political and world wide economic conditions would have on energy supply and demand. Hence, developing technologies have been left in an uncertain stage early in their development.

In the fossil energy arena, the following factors illustrate the dilemma the country now faces. In 1981, eight major synthetic fuels projects were in various stages of development:

(1) H-Coal,
(2) SRC-II,
(3) Exxon Donor Solvent,
(4) SRC-I,
(5) Colony Oil Shale Project,
(6) White River Oil Shale Project,
(7) Union Oil Shale Project, and
(8) Great Plains Coal Gasification Project

An examination of these projects today shows that the H-Coal, SRC-II, Exxon Donor Solvent, and Colony Oil Shale projects have been cancelled. Furthermore, the SRC-I project is now highly uncertain, and there has been recent speculation about the viability of the Great Plains Gasification project. The economic viability of the Union Oil and White River Oil Shale projects is still a matter of concern. Hence, we see that a combination of uncertainties in the marketplace at the present time coupled with technical difficulties have conspired to eliminate a large portion of this nation's synthetic fuel effort.

While it can be argued that today's "oil glut" obviates the necessity of a synthetic fuels industry, the total world oil supply has not changed significantly. Problems associated with securing adequate energy resources in the United States have not changed. A rebound in the world's economy or changes in the world's political alignments can eliminate the present oil glut and re-create an oil shortage almost overnight. The present oil surplus can only be expected to be a temporary situation, and, sooner or later, market conditions can be expected to change.

Characteristics of the three forms of energy vary greatly from state to state and region to region. Fossil energy varies with respect to both the characteristics of coal and other fossil energy forms, but, more importantly each form of energy has different impacts upon the environment depending upon where the conversion system is located and which conversion process is used. The same coal burned in one type of power plant in one part of the country must be handled differently in another part of the country where the wind and environmental conditions vary by substantial amounts.

State and regional differences are even more pronounced with respect to conservation, solar, and other renewable energy systems. Conservation in the North primarily relates to cutting heat losses in buildings during the winter. In the South, it is primarily related to loss of cooling and rising air conditioning costs. Universities are a particularly valuable resource in the United States for adapting general research to specific state and regional needs. The proposed reductions in the budget in these institutions are especially detrimental to the future of university research and to the relationships of these universities to the industry and culture in the locations where they operate. Unlike fusion energy which is much the same in Florida as it is in Maine, fossil and renewable energy systems vary enormously by location and use. Furthermore, the impact of short-range and long-range energy sources is undoubtedly more significant in fossil and renewable energies. The technical challenges are great especially if one considers the diversity of needs. The research needs, which are different from state to state and region to region, require sophisticated, important, and long-term high-risk research. The very fact that they are locally oriented makes them a higher-than-normal risk because the benefits of research are not generally applicable nationwide to a single size or a uniform market. Thus, recovering research expense is more difficult and challenging. The very complexity of regional needs means that Federal support for research and development in these areas is more important, not less important. Energy savings anywhere in the U.S. means more net energy for the nation. And we recommend to you that these enormous and devastating budget cuts be reconsidered and reversed. In fact, instead of deserving budget cuts, these are among the most promising areas for future success in serving the energy needs of the United States, and we encourage you to consider expansion of research and development programs rather than the proposed reductions.

Renewable energy systems already provide for this country twice as much energy as does nuclear energy and are growing at a much faster rate. We would further point out that renewable energy systems frequently supply the low grade thermal energy needed in industry and in our homes in ways more efficient and at a lower cost than with the complexities of nuclear electric power generation. We would also point out that the demand for electric power in this country is declining primarily because of the success of energy conservation and improvements in energy efficiency. Continued improvements in energy efficiency will focus energy needs of the future on low grade areas of renewable energy and coal generation to the extent that big centralized, inefficient energy systems will be in less demand.

The last few years have dramatically illustrated that the character of energy mix in this country is dramatically changing away from oil and nuclear energy to distributed coal, co-generation, and renewable energy systems. The technical complexities of distributed systems are at least as great as those centralized systems. There is today no less need for Federal support of research and development in these energy areas: in fact, the need is most acute. The primary difference is that long-range high-risk energy research and development activities in coal, energy conservation, solar, and other renewables will obtain more rapid technology transfer, widespread utilization, and increased economic development stimulus on the local level. Many of these energies systems are labor intensive; thus, they will contribute immediately and in the long range to a reduction in unemployment, particularly among less well-trained workers.

We urge you to reconsider national priorities in energy research and development and move programs and funding into universities where Federal money will be multiplied by state and regional resources and where the powerful and important byproduct of greatly increased manpower development will contribute now and in the future to the country's energy independence and achievement. For each dollar of energy research and development placed in a university, about twenty-five cents is used to support students who contribute to the needs of the country for the next forty or more years after their training. In contrast, every dollar placed in a national lab pays less than one cent to support students who contribute to the future energy manpower needs of the country. University energy research and development is not only lower in cost and more efficient than research in national laboratories, it contributes the important additional element of enhancing and enlarging human resource achievements. Also, universities can readily transfer technology directly to industry through joint research programs.

One particular problem is deleterious to basic University research. I refer to the increasing obsolescence of the instrumentation and equipment in use in this nation's laboratories - be they part of national laboratories or universities. It is difficult to quantify the undesirable consequences of the dearth of first-rate instruments. It is certain that this nation's technological preeminence is slipping, and the overwhelming consensus among knowledgeable scientists is that equipment obsolescence in the research laboratories of this country is an important contributing factor.

Energy research and development in the United States today is primarily planned by the agency from the top down. This is the legacy of the Atomic Energy Commission where a few people made crucial decisions, and these decisions were implemented by the bureaucracy with little evaluation or interpretation. Changing times, especially in non-nuclear areas, now indicate that we should have an energy research and development program that is based on a "bottoms up" philosophy. This means that local and regional needs should be organized and formulated and coordinated at the national level so that energy research and development programs serve the whole country in an intimate network that has the support and understanding of all the people. A model of the past is agricultural experiment stations. We urge you to abandon the old and now outmoded system of "top down" planning of energy research and development and move to a new system that involves a greater understanding and input from all states and all levels in our society. We are sure that any such approach will indicate that a dramatic shift of resources into programs that support conservation, coal, energy utilization and the development and utilization of renewable energy systems will be the primary focus both now and in the next century when these systems will contribute most to the future energy needs of this country.

I thank you for the opportunity to submit this testimony.

Senator **Warner**. Thank you very much. Our final witness for the day, Mr. Harold Seielstad, chairman, Central Receiver Council of Solar Thermal Division.

STATEMENT OF HAROLD E. SEIELSTAD, CHAIRMAN, SOLAR CENTRAL RECEIVER COUNCIL, SOLAR THERMAL DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

Mr. **Seielstad**. Thank you, Mr. Chairman. My name is Harold Seielstad. I am director of the solar research and development and demonstration program of the Pacific Gas & Electric Co., and chair the Solar Council of the Solar Energy Industries Association.

I appreciate this opportunity to present a brief summation of our written testimony on the fiscal 1984 solar thermal R&D budget.

It is just a decade ago that the first abrupt petroleum price hike was felt around the world. That may prove to be one of the most salutory events in the history of solar energy. It made many realize that petroleum must be treated as capital, not as interest, that it is indeed finite and diminishing, and we need to reduce our dependency on it.

One significant element in the national energy plan to decrease petroleum dependency must be to increase solar dependency. Two favorable actions by this Congress this year will accelerate the path toward balanced energy resources. The first of these is affirmative action on the R&D needs of the solar thermal industry in fiscal 1984. The $52½ million budget proposed by industry is minimal, yet adequate to maintain progress toward commercialization. It is a product of numerous meetings and conference calls, compromises and consultations with industry, DOE and congressional staff and others. Any reduction will seriously retard the advance of solar technology which has already suffered setbacks beyond its control.

Specifically this budget involves three major solar thermal technologies—solar central receiver, parabolic dish, and parabolic trough. The budgetary items for the solar receiver, $25.1 million, will have a major impact on bringing this technology to commercial fruition. The $8 million cost shared repowering program and $10 million in supporting technology will identify and reduce the risk to the point where manufacturers can engage the still substantial risk of providing fixed price contracts and performance warranties. The venter capitalist will only then be enabled to fund the series of powerplants and create an economically attractive resource in a post-tax credit period.

Continued funding of the Solar One pilot plant is vital. Completion of the augmented control system and continuation of operations will advance the data base; the $14½ million parabolic dish technology focuses on further development of both the Stirling cycle module and testing of those at the parabolic dish test facility. This technology offers substantial potential for distributed solar energy at high conventional efficiencies.

The parabolic trough program, $1½ million is being phased out in this final fiscal year, it having reached the point of commercial viability. Finally, testing at Myers and SERI of four systems will provide a documented performance base for industry adoption.

These three programs are further advanced by $6.9 billion recommended for long-term research on materials and processes conducted at the national laboratories and universities for the second generation of solar thermal technologies.

The solar pond program has been reviewed by DOE's task force which has not yet submitted its recommendations for further work. Thus we have reduced this system this year and will recommend new items for fiscal 1985.

We also recommend that the additional $1½ million that was provided in fiscal 1983 for minimal support of the repowering program be reprogramed from the unexpected $1½ million in 1983 for the solar pond program.

The second required congressional action is upon the solar tax credit issue. Although it is not within the purview of this committee, I want to urge the extension and enhancement of the business energy tax credit. Measures such as H.R. 1774 introduced by Congressman Fuqua is an essential companion to the R&D budget to commence the expeditious commercial production of solar thermal technology. The Tax Equity and Fiscal Responsibility Act of 1982 has reduced the effectiveness of the tax credit. This reduction in rate of return reduces the viability of solar investment versus other opportunities. Also reduction in the avoided cost payment by utilities has further reduced the financial viability in the short term. We urge the Congress to recognize the need of the emerging industries of the 21st century into a robust adolescence, and to avoid the futility of subsidizing a stagnating industry.

Such policies in foreign countries are showing substantial promise of generating new long-term jobs and taxable products and services.

In summation, I urge the committee to manifest the long-range vision of the energy needs of our Nation. We must reduce our dependency on nonrenewable fuels and increase our dependency on renewable fuels. Maintaining this transition to that which is inevitable is one vital element in a balanced national energy plan. The quantitative introduction of solar thermal resources provides a break on the acceleration of petroleum prices, reduces the utilization for heat and electricity, and extends its availability for transportation and other vital uses.

I am hopeful this committee will approve the $52½ million solar R&D budget and assist other committees in passing the solar tax credit enhancement and extension, thereby providing minimal basis for realization of substantial potential of these technologies.

I appreciate your time, and I will be glad to respond to any questions.

[The prepared statement of Mr. Seielstad follows:]

STATEMENT OF

HAROLD E. SEIELSTAD

CHAIRMAN

SOLAR CENTRAL RECEIVER COUNCIL

SOLAR THERMAL DIVISION

SOLAR ENERGY INDUSTRIES ASSOCIATION

BEFORE THE

SUBCOMMITTEE ON

ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

U.S. SENATE

May 3, 1983

1.0 ABSTRACT

As a result of the government-industry partnership that is occurring, the past year has seen a number of significant accomplishments for the solar thermal industry. Among these are the operation of the Solar I central receiver pilot plant, the central receiver repowering preliminary design cost sharing programs, the Solar 100 solicitation, the successful testing of the parabolic dish-Stirling system, and the successful parabolic trough Modular Industrial Solar Retrofit (MISR) program. The central receiver and the dish technologies are in a critical stage of development and require continued direct DOE support through FY 1985 and FY 1986, respectively, in order to cross over into commercial viability. Direct support of the parabolic trough industry can be phased out in FY 1983.

An extension and enhancement of the Federal energy tax credits is required to assist these fledgling industries to compete and attract investment capital during the transition period from cost-sharing government support to a free-market, job-producing, competitive energy option.

The solar industry, through the Solar Thermal Division of the Solar Energy Industries Association, recommended, in recent testimony before the House Subcommittee on Energy Development and Applications, a budget of $53.2M for solar thermal activities for FY 1984. The Subcommittee, in turn, recommended a budget of $51.0M. The Solar Thermal Division, in response to this action, has reduced its recommended FY 1984 budget to $52.5M and is suggesting some small changes in priorities which will more closely reflect the intent of the House Subcommittee.

2.0 INTRODUCTION

Mr. Chairman, members of the Committee, the Solar Thermal Division of the Solar Energy Industries Association (SEIA) is appreciative again this year of the opportunity to testify on the Federal budget pertaining to the solar thermal technologies. Once again significant accomplishments and positive outlooks for the future have marked this past year as a result of the government-industry partnership that is occurring. As an industry association, we can now envision, with an approximately level out-year budget, a complete phase-out of direct Department of Energy funding by the end of FY 1985 for central receiver technologies and by the end of FY 1986 for the parabolic dish tech- nology. As the industry has promised, direct, in-budget support for the para- bolic trough technologies can be phased out in FY 1983. As of the above dates, the remaining direct technical research and development risks will be regarded as manageable by private industry. However, long-term, high-risk research of a generic nature that is applicable to all technologies is recommended as a logical policy for the Federal government in the more distant future.

With regard to a vital and related issue, it is essential to note that the successful transition of these three technologies from cost-shared, direct government support to the private sector and thence to commercialization will depend upon the retention of the energy tax credit, as well as other existing, related legislation. In view of such events as the passage of the Tax Equity and Fiscal Responsibility Act (TEFRA) and the decline in the cost of oil and natural gas, an enhancement of the current energy tax credit to 25% for the time period from now to December 1990 and an affirmative commitment provision to extend the 25% tax credit to December 1993 is necessary.

2.1 THE SOLAR THERMAL DIVISION OF SEIA

The Solar Thermal Division of SEIA is an industrial organization fulfilling a vital role in the commercialization of solar thermal systems. The member companies have consistently been at the forefront in advancing solar thermal technology through commitment of their own resources in close cooperation with federally supported research and development programs in solar energy. Ranging in size from large, multinational energy and aerospace corporations and utilities to small, innovative firms, the Solar Thermal Division members are world leaders in solar thermal technology. This leadership is based on experience gained through the 1970s, beginning with the early efforts of the National Science Foundation Solar Program. Nearly 10 years of accelerated effort have led to the development of advanced system designs that have exceeded almost all performance expectations. The transition from early engineering and test prototypes to full-scale operating systems for industrial and utility users is nearing reality. Further information can be found in the Solar Thermal Division (STEA) brochure which is attached.

2.2 TECHNICAL DIVIDENDS

Industry has responded to the policy shifts in energy research and development by advocating and implementing an orderly transition from system level engineering to a program with more emphasis on applied research and development. Important at this stage in this technology's development is the need to preserve the vast federal and corporate investment represented by existing test facilities. It is also important to continue and complete the component development program and last-step engineering phases that will help propel industry over the last major research and development risks that remain.

I know of no other renewable energy program that has met with more technical success, given the magnitude of the technical complexity. The government-industry partnership is working, and the end of direct support is within sight. A maximum of 3 years of additional direct support of the major technologies at approximately level funding, relative to FY 1983, would appear to be adequate to complete the transition.

I firmly believe that the balance of this testimony will establish that there are significant technical dividends that have resulted from this committee's support of solar thermal technologies. I also believe that the work accomplished to date and the prospects for the future justify our FY 1984 budget request.

2.3 ERAB REPORT

The FY 1984 program that is proposed today is highly supportive of the recommendations made by the Energy Research Advisory Board to the Deputy Secretary of DOE on October 12, 1982 (see Appendix A). The ERAB report established the state of the industry and the appropriate roles for future solar thermal research and development. The ERAB recommendations include:

1) For the central receiver program, the cost sharing of receiver and storage concepts, continued federal support for the operation of Solar One, system component development and tests at CRTF, cost-shared projects for repowering and extension of the business energy tax credit. Included in the Solar One support is a requirement to complete the plant's automatic control system.
2) For the parabolic dish program, DOE should redirect its emphasis to this program to further technology development. Small multi-module experiments should be planned on a cost-sharing basis.
3) For the technology base R&D program, a number of critical areas have promise for providing the base necessary for the next generation of solar thermal technologies, including improved

central receiver, dish and trough systems, with considerably improved performance and reduced energy costs. These include:

a) The development of new materials with good optical qualities and long life
b) The development of lightweight, low-cost concentrating structures
c) The development of high temperature materials
d) Research, which should be coordinated with similar activities in the biomass energy area, into the use of thermal processes for fuels production .

3.0 SIGNIFICANT ACCOMPLISHMENTS

3.1 CENTRAL RECEIVER

The past year has seen several significant events heralding the development of the solar central receiver as a viable energy source:

1) The 10-MWe, Solar One power plant near Barstow, California, became operational on April 12, 1982, and was dedicated in November 1982.
2) Four repowering preliminary design contracts with cost sharing between industry and DOE were established.
3) Southern California Edison requested proposals from industry for a Solar 100 plant and received four responses.

3.1.1 Solar One

The 10-MW solar thermal central receiver pilot plant became operational in April 1982 and is currently the world's largest electric generating station being successfully powered by solar energy.

This plant was the result of a joint effort among the Department of Energy, Southern California Edison, and the Los Angeles Department of Water and Power. The plant has operated at 10.4-MW net electrical output, which is slightly in excess of its rated output, and has produced over 2,000,000 kWh of net energy while connected to the utility grid. Very recently, a power of 7.3 MWe from storage was achieved, an accomplishment which satisfies another design milestone for the plant.

It is especially noteworthy that within the last few months the plant has exhibited an availability of greater than 90% and that more than 98% of the heliostats are capable of operation at any given time. The latter fact is especially important relative to the acceptability of this energy option to the user industry.

The 5-year test program is well underway and the pilot plant has demonstrated that the central receiver concept works as expected. The first 2 years of the test program will be devoted to design verification of the individual systems and components and will serve to verify the various modes of operation. Additionally, plans call for fully automated controls so the plant can be operated with a minimum operating staff, and the collector system will be integrated into the overall control system. The last 3 years of the program will maximize kWh output and demonstrate plant reliability.

Solar One is now operating on weekends as a power plant.

3.1.2 Repowering

Four preliminary design studies for solar central receiver power plants are well underway. These contracts involve significant cost sharing between the industry participants and the DOE. Three of these plants are for utility power generation with sizes ranging from 30 to 66 MWe. One uses liquid sodium, another uses molten salt, and another uses water as the heat transport fluid. The fourth preliminary design is a 31.8-MWe industrial cogeneration project in Hawaii using water as the heat transport fluid. Three of these projects are midway through the contract phase, but the study utilizing sodium as a heat transfer fluid is based on an accelerated schedule in order to attempt to be on line in mid-1986. This 30-MW plant is the intermediate step between Solar One and a series of 100-MW commercial modular solar power plants. The results to date from all projects have verified performance characteristics, reduced technical uncertainties associated with operating activities such as startup and shutdown, and reduced cost uncertainties.

All of these projects are struggling to maintain favorable economic characteristics for the plants in the face of decreasing fossil fuel costs and the potential loss of the energy tax credits after 1985. The 30% drop in California avoided costs and the reduction in the effective value of tax credits caused by TEFRA have undermined promising economics, making tax credit enhancement and extension vital to the generation of pre-commercial plants.

The industry is responding aggressively to the PON that was recently issued for the final design effort on repowering and for subsystem research experiments in fulfillment of Congressional guidelines.

3.1.3 Solar 100

Southern California Edison has been among the leading utilities in expressing interest in renewable energy sources, with a commitment to 2100 MW by the early 1990s. Of this, 350 MW electric has been designated to come from solar energy. In addition, there is strong interest on the part of a number of other utilities in the Southwest in more than 30 follow-on, 100-MW, central receiver plants for capacity additions by 2000. SCE has given an incentive to industry through its Solar 100 solicitation. The four companies that responded to the SCE request for proposal to design and construct a 100-MWe central receiver utility standalone plant at the Lucerne Valley site in California's Mojave Desert expressed confidence in the technologies that are available and optimism that financing can possibly be worked out. However, SCE is not in a position to purchase the plant outright but would buy energy from an independent power producer which would own the plant. Hence, the capital investment required would depend on third-party financing. Two of the four companies are actively pursuing funding for power plants with a power level intermediate between Solar One and Solar 100 on the basis of developing the technology in smaller steps and reducing the amount of third-party financing required. This situation underscores the importance of the availability of energy investment tax credits through 1990.

3.2 PARABOLIC DISH

During the past year, the U.S. Department of Energy continued to coordinate the development of Rankine, Stirling, and Brayton engine/receiver combinations. Since last March, additional significant milestones have been reached on the path of developing dish electric systems for efficiently and reliably producing electricity. The development of the Stirling engine technology has been enhanced by substantial cost-sharing activities between industry and DOE. In April 1982, testing confirmed the technical feasibility of a hybrid (i.e., combustion-augmented) dish Stirling receiver. After reviewing several competing proposals, DOE signed a cooperative agreement in May 1982 with a team of industrial contractors for a cost-shared experiment for the design, fabrication, assembly, and test of a complete dish-Stirling module. Under its own resources, the engine manufacturer designed and fabricated three experimental solar-only receivers and one engine. Under a joint industry-government project that had significant cost sharing by the industrial participant, a full system test was carried out and demonstrated an electrical power output of 24 kWe near solar noon on July 15, 1982. This event set a new record in solar energy development, since a solar-to-electric conversion efficiency of approximately 29% was recorded. This efficiency is the highest achieved to date by any solar thermal energy conversion technology.

A two-phased approach to developing the Brayton-cycle technology was recommended in a system tradeoff study completed in April 1982. The study concluded that the first near-term Brayton module should use a small 8-meter-diameter parabolic dish designed and funded entirely by industry. This dish would be coupled with the subatmospheric Brayton-cycle (SABC) engine under development in the Gas Research Institute program. This study recommended that subsequent, more advanced system designs should incorporate the high-efficiency Brayton technology based on the ceramic advanced gas turbine (AGT) which is currently under development in DOE's Automotive Engine Program. During the past year, industry initiated testing of the advanced gas turbine at an industry facility and fabricated an early solarized version using a metal turbine wheel rather than one constructed of ceramic. The solarized advanced gas turbine (SAGT-1) was combined with an air-Brayton receiver and will be tested at the Parabolic Dish Test Site this summer.

The organic Rankine-cycle technology will be field tested in the Small Community Experiment. In July 1982, DOE announced its selection of Osage City, Kansas, as the prime site for the experiment, with Molokai, Hawaii, as a backup. As a preliminary step in this experiment, verification testing of the organic Rankine-cycle power conversion assembly on a test bed concentrator was completed at the Parabolic Dish Test Site in April 1982. The maximum power output achieved during the testing was 16 kWe with an overall module efficiency of 19%.

In September 1982, the fabrication and installation of a prototype dish concentrator was completed. Characterization testing of this prototype concentrator with a plastic-film reflective surface is nearing completion at the PDTS. A thermal output of 75 kW, which approaches the expected performance level, was achieved in February 1983.

With regard to the status of dish technology, the Industry Association is dismayed that the Department of Energy has indicated to the Senate Appropriations Committee their intentions of submitting a FY 1983 deferral on the $3.0M system test and evaluation of the Brayton and/or Stirling modules and an additional $2.0M in solar pond research. The Energy Research Advisory Board recommended in October last year that the Department should reemphasize the parabolic dish program and support multimodule experiments on these high conversion technologies. Should the Administration submit these two deferral items, then the Industry Association would urge your support for these two essential projects, even though, in the case of the solar pond work, we recommend only a small effort be supported.

3.3 PARABOLIC TROUGH TECHNOLOGY

Line focus technology is generally accepted as ready for commercialization, and, in a general sense, this conclusion is true. All manufacturers of parabolic trough collectors are currently marketing, with some success, to industry without DOE subsidy. However, the recent drop in the price of petroleum has caused many projects to be postponed.

The basic parabolic trough systems are well developed and not in need of continued support by DOE in terms of development of the specific parabolic trough concept. The basic system characteristics are fairly well understood, with IPH systems being the most developed. The Modular Industrial Solar Retrofit (MISR) Program, supported by DOE funding, has been very successful and has resulted in the completion of the concept design phase of the line focus development program. The MISR concept features a modular solar industrial steam system and is the final phase of testing and component improvement.

There remains one small area of line focus technology development which is in need of DOE support in a generic sense. In this sense, the work will be of use to several technologies. This area is one of high-risk research and material development. Of particular importance is consideration of reduction of thermal loss from the receiver subsystem and the enhancement of reliability and performance.

Some of the materials which require further development support are reflective surfaces, antireflective coatings, selective coatings, seals, and heat transfer fluids. It is the opinion of the parabolic trough industry that this development support can be most effectively implemented at Sandia National Laboratories in Albuquerque.

Completion and support of current IPH experiments, along with continued support of high-risk material research, will achieve the goal set for the line focus technology.

3.4 SOLAR PONDS

Solar ponds are applicable to the production of process heat and electricity. The technology has, to date, been principally developed in Israel. From the standpoint of viable economics, it is geographically restricted to areas where natural salt lakes exist or can exist and where the cost of providing dikes can be minimized. Among questions to be resolved are maintenance of water clarity, local brine production, permeability of ground under the pond, suppression of waves, salt gradient stability, maintenance of the salinity and thermal stratification, and environmental protection. A moderate level of continued R&D is desired prior to any demonstration projects being undertaken.

4.0 STATE OF THE INDUSTRY

4.1 EXCERPTS FROM SEIA REPORTS

The Solar Thermal Division of SEIA has prepared a number of reports regarding the status of the solar thermal industry, the international market, program plans, and government incentives. These reports can be summarized as follows:

1) Status of the Solar Thermal Industry: An Assessment, December 1982

> "The solar thermal industry, which includes companies developing parabolic dish, parabolic trough, and central receiver systems, is on the verge of commercialization. Though it faces no major technological problems as a new and vulnerable industry that has yet to make its first significant private commercial sale, it is still quite dependent on federal support in the form of R&D, field engineering tests, and tax credits. Twelve out of sixteen solar thermal companies considered in this report are dependent on direct government support to a substantial degree. Half of these are getting 25-50% of their R&D funds from the government, the other half are 80-100% dependent. The four currently not getting federal support had been [receiving it] until recently. One-third of the respondents believed their companies would drop out of solar thermal development if direct federal support were cut off. Those most likely to drop out were central receiver and dish companies; trough company respondents believed their companies would be set back, but probably would not be forced out of business."

2) DOE Solar Thermal Energy Program On-Line Budget Analysis 1983 (January 1983)

"In regard to DOE FY 1983 planning, industry is most interested in technology R&D that helps it get currently conceived projects off the ground. There is less appreciation for large sums of money being spent on more sophisticated, longer range con- cepts, such as a solid particle receiver concept. The industry appreciates the apparent need to mollify the Administration with "long range, high isk" approaches but it is not willing to go along at the expense of dissipating near-term momentum from the pre-existing program. DOE appears to have failed to adequately project a long-range strategy for solar thermal energy development that would disarm industry fears of the pro- gram being cut well beyond the bone."

3) Section 210 of PURPA and Solar Thermal Energy Development: The Current Regulatory Environment and Suggestions for Future Action (January 1983)

"On a macro-scale, PURPA §210 and its implementation to date by FERC and State regulatory authorities have created a regulatory environment which is basically favorable to solar thermal and other QF development. A much larger number of solar thermal facilities are being planned, proposed and negotiated than was the case prior to PURPA. Although PURPA cannot be demonstrated conclusively to be the principal cause for increased interest in solar thermal facilities, PURPA appears to be a contributor to favorable conditions for solar thermal development. PURPA seems to be accomplishing its major objectives of exempting QF's from burdensome regulation as electric utilities, and creating a climate for fruitful discussions with electric utilities."

The report contains a summary and analysis of possible amendments to PURPA with the following subject matter:

1) Raising the maximum power level for small power production facilities
2) Eliminating or altering current PURPA restrictions on utility ownership of QFs
3) Setting rates for QF-generated electricity
4) Reducing interconnection costs and making interconnection easier
5) Extending exemptions from other laws.

4) Options for Federal Income Tax Incentives for the Solar Energy Industry (February 1983)

"Federal income tax incentives can play an important role in carrying out our national policy of encouraging and accelerating the development of the solar energy industry. In the past, American economic policy has been to support declining industries, whereas the economic policy of some more rapidly expanding nations, such as Japan, has been to encourage new industries. A program of support, including tax incentives, for the solar energy industry would encourage a new industry which may become crucial to U.S. security and economic stability.

"To offer the greatest probability of success, the tax incentives should include provisions benefiting consumers of solar products, manufacturers of such products, and investors in such manufacturers. Incentives to consumers will encourage development of a market for solar products which will present manufacturers with a source of funding, provide them with experience in marketing, and afford opportunities to test and improve products. Incentives for the manufacturers and investors will encourage capital formation in the solar industry through tax shelters, venture capital and more conventional investments, and by reducing the tax drain on such capital. Tax incentives could obviate or reduce the need for direct government support of the industry, and, by contributing to the more rapid growth of the industry, create jobs, income and tax revenues."

5) International Solar Thermal Market Assessments: An Evaluation (December 1982)

"Most of the international market assessments for solar energy are useful only as introductions to help exporters decide which countries to choose for future study. These reports contain general background material, such as energy resource data, rather than rigorous economic analyses or sales projections as a potential exporter of solar thermal systems needs to make real investment decisions. The market assessments, mostly for third world countries, focus on low temperature, solar heating and cooling, and photovoltaic technologies that can be used in small scale, remote site, and rural applications, and therefore seem more suitable for less developed nations. The reports largely ignore the possibilities for large scale, solar thermal electric power plants."

6) Impediments to Capital Formation in Solar Thermal Energy Systems (February 1983)

"A firm's decision to invest in a particular project is dependent upon a number of factors, chief among them are the availability of capital, the cost to the firm of that capital, the anticipated future stream of earnings associated with a specific project in the light of any uncertainties inherent in that stream, and the appropriateness of a given project within the firm's overall investment portfolio. To attract capital, a solar thermal project must possess two basic attributes. First, it must provide returns, in the form of future earnings or avoided costs, that are commensurate with its perceived risks (both financial and technical). The old maxim that high risk goes with high reward, low risk with low reward is apt. Beyond this, it must be apparent to potential investors that the magnitude and certainty of such returns are preferable to alternative investments currently available including fossil, wind, etc. As much less commercial experience exists with respect to solar thermal than its competitors, it is strongly penalized for risk. That is, the quality of returns, being less certain, is heavily discounted. More commercial experience with solar thermal is necessary before such fears can be allayed.

"Given the current outlook for energy prices and the investment climate, the continued development of a commercial solar thermal industry in the mid to late 1980s is depending on strong Federal initiatives."

7) Solar Thermal Program Strategy (January 1983)

"Neither potential users of solar thermal energy systems nor the investment banking community appear willing to accept the large risk at the present time in adopting solar energy systems. This means the federal government must continue to support, at a minimum, and with substantial cost sharing by industry, component and subsystem testing so that users can be convinced of the merits of the technology. This immediate agenda must be continued and then complemented with the longer range view. There is a danger DOE would emphasize longer range research and development before the first phase in solar thermal development is really complete; that is, carrying current technology into a safety zone which ensures a solar thermal industry exists to benefit meaningfully from longer range development.

"Industry is accused of being so preoccupied with nearer-term development of solar thermal technology and its commercialization that it ignores the implications of what needs to be done in the mid-term to ensure a smooth transition to the satisfaction of longer range goals. The industry contends that it has adopted a responsive position, manifest in its proposals that funding for current technologies (troughs, dishes, and central receivers) phase out in the mid 1980s. There remains a gap, however, in the positions taken by industry and the Administration over strategy. A closing of the gap must still be accomplished if the solar thermal program is to proceed smoothly through the 1980s to realize its long-term potential."

4.2 ENERGY TAX CREDIT EXTENSION

The Solar Thermal Division of SEIA recognizes and agrees that there is a need to reduce federal spending in the near term and that direct federal support for certain specific solar systems should be phased out in an orderly and timely manner. In keeping with this strategy, the industry recommended significant reductions in solar thermal budgets for FY 1983, proposed significant cost-sharing arrangements under those budgets, and presented a phaseout strategy whereby direct support ended for the parabolic trough technologies, for the central receiver technologies, and for the parabolic dish technologies at the end of FYs 1983, 1985, and 1986, respectively. Under these circumstances, the industry's understanding was that the 15% energy tax credit, the depreciation schedule of 5 years for certain solar energy equipment, various provisions of PURPA, and other key off-budget items would remain intact as an aid in getting the technologies into the private sector. However, in the interim, the Tax Equity and Fiscal Responsibility Act (TEFRA) of 1982, which significantly reduces the effective value of the tax credit, was passed. In addition, there has been frequent pressure put forth by the Administration to delete the tax credit altogether, and there was a recent indication of a thrust to change the depreciation schedule. Finally, the decline in the price of petroleum has further exacerbated the economic competitiveness of these solar technologies. All of these factors have a strong deleterious effect on industry's goal of getting these solar technologies completely into the private sector where they can be commercialized and where they can make a significant contribution to our energy options and energy independence.

In view of these circumstances, the Solar Thermal Division of SEIA developed a tax credit position late last year and now feels that it is essential that an energy tax credit at the 25% level be made available over the time period from the present to December 31, 1990, and that a provision be included to extend the credit at the 25% level to December 31, 1993, for projects that have made an affirmative commitment to construct by the December 31, 1990, date. There are several reasons why we feel that this request is reasonable. First, the 25% tax credit effectively restores, with a slight margin of enhancement, the tax credit to the value it had prior to TEFRA. Secondly, many projects require 3 to 4 years to carry out, and money, in some cases in the amount of several hundred million dollars, must be raised at the beginning. Thus, projects of this type cannot be planned and money probably cannot be raised by investment bankers if the current December 31, 1985, termination date remains in effect. In summary, an extension to the 1993 time period is essential to plan and carry out the many large and small projects which will have a strong influence on the user industries in terms of adopting the technology under a purely free-market situation. In addition the stability of the tax credit legislation provisions, as well as a host of other related legislation such as PURPA and depreciation schedules, is essential to the success of transferring these technologies to the private sector.

It should also be recognized that the solar thermal technologies are principally oil and gas replacement technologies. Both industry and utilities expense fossil fuel purchases prior to calculation of corporate income taxes. This procedure constitutes an indirect, but substantial form of subsidization and works against the adoption of a no-cost fuel (solar energy) which has high front-end capital costs associated with it. Since it is in the national interest to reduce dependency on imported petroleum, it is reasonable to recommend equivalent treatment for solar energy.

4.3 DWINDLING OIL PRICES

A reasonable question at this time would be to speculate as to the impact of dwindling oil prices on the commercialization of the solar thermal technologies. It is not possible to state specifically the impact with any degree of certainty, but several generalities can be offered.

First, a sustained reduction in oil prices will delay the introduction of these technologies and possibly extend the payback of the projects that are imminent. Conversely, if lower oil prices significantly hasten the economic recovery, and if lower interest rates occur, then the financing of these systems will be enhanced.

Second, from a public interest viewpoint, we are deeply concerned over the number of large synthetic fuel projects, oil and gas exploration projects, and alternate fuels projects that are being terminated or indefinitely suspended over this current event. I am sure it has not gone unnoticed that such terminations will keep America indefinitely vulnerable to OPEC and/or any supply disruptions caused by political, military, or terrorist actions abroad. Such a major disruption in availability of imported oil as is being currently studied by the Congressional Office of Technology Assessment would create a major instantaneous rise in the price of oil, and thus instantaneous competitive attractiveness of solar thermal technologies. The relatively short lead times (1 to 4 years) required to implement solar thermal technologies and their long-term growth potential as an alternative to fossil fuel is our most persuasive argument for a sustained industry-government partnership in developing renewable energy technologies.

5.0 PROPOSED FY 1984 BUDGET

The Administration's FY 1984 budget request for the Solar Thermal Technologies discussed today is only $13.4 million. This figure represents only a fraction of the past solar thermal budgets, and, for the third year in a row, the Administration has formulated a budget request that is less than one-third of the preceding year's authorization.

The STEA considers the Administration request inadequate in light of the significant accomplishments and the remaining tasks. Included herein is a comprehensive alternative budget that totals $52.5 million. In the next section we have spelled out our rationale for each line item. We feel that our submission represents a realistic and balanced approach to the development of solar thermal energy. The difference in the two budget requests represents the difference between having a viable, job-producing industry, or, potentially, none at all.

SOLAR THERMAL DIVISION
BUDGET RECOMMENDATIONS
FY 1984
(DOLLARS IN MILLIONS)

A.	LONG-TERM RESEARCH		6.9
1.	Materials	2.0	
2.	Collectors and Concentrators	1.5	
3.	University Thermal Research	1.4	
4.	Sunfuels Research	2.0	
B.	CENTRAL RECEIVER RESEARCH AND TECHNOLOGY		2.0
1.	CRTF Operations	2.0	
C.	PARABOLIC DISH RESEARCH AND PROJECTS		14.5
1.	Component Development of Modules	6.0	
2.	Advanced Concentrator Development	2.5	
3.	System Test and Evaluation	3.0	
4.	Applied Research and Test Facilities	2.0	
5.	Test Facility Operations	1.0	
D.	SOLAR PONDS RESEARCH		0.5
E.	CENTRAL RECEIVER SYSTEM AND COMPONENT DEVELOPMENT		25.1
1.	Solar One Automation and Controls Software	2.0	
2.	Solar One Operations, Maintenance, and Analysis	5.0	
3.	Repowering	8.0	
4.	Receiver Development	4.1	
5.	Storage Concept Development	1.0	
6.	Steam Generator Development	3.0	
7.	Control System Development	2.0	
F.	DISTRIBUTED RECEIVER SYSTEMS		1.5
1.	Operations and Evaluations	1.5	
G.	PLANNING AND PROGRAM SUPPORT		2.0
			52.5

SOLAR THERMAL DIVISION
SOLAR ENERGY INDUSTRIES ASSOCIATION
BUDGET RECOMMENDATIONS AND SUBSTANTIATIONS FOR FY 1984

The rationale for each item in the STEA budget recommendations is presented in this section.

A. LONG-TERM RESEARCH

1. MATERIALS

Although materials are available to fabricate and operate solar thermal systems successfully at the present state of the art, there is room for improvements in this area from the standpoint of both performance and cost reduction. In the long term, improved materials will make all of these technologies more efficient and therefore more cost competitive with other energy alternatives. Such long-term, generic research falls within current DOE guidelines in terms of risk and the time it takes for such research to be adopted by the private sector. STEA recommends generic research at a $2.0 million level for FY 1984 in such areas as reflective surfaces, antireflective coatings, selective coatings, seals, improved glass, and higher strength materials.

2. COLLECTORS AND CONCENTRATORS

Many aspects of collector and concentrator research are generic in nature and apply in one degree or another to parabolic troughs, parabolic dishes, central receivers, and other solar systems. In this area, work that results in improved performance and in reduction in capital costs, or both, is important to the long-term viability of solar thermal systems. The industry feels that this line of investigation is justified and recommends $1.5 million be expended in FY 1984.

3. UNIVERSITY THERMAL RESEARCH

Research work carried out by U.S. universities has been useful in the past in identifying promising concepts and processes in solar thermal technology. The industry feels that such work should be continued in FY 1984 and beyond at the $1.4 million level in 1984 dollars. In the view of industry, this research should have a very general goal of identifying, analyzing, and carrying out laboratory scale and test facility experiments on processes that can potentially have a significant impact on energy independence, stabilization of energy prices, and reduction of energy imports.

4. SUNFUELS RESEARCH

Although the solar thermal industry recommends that R&D in the area of the application of solar thermal processes to the production of fuels and chemicals be conducted, we do not feel that it should have a high priority since it cannot have a near-term impact on stabilization of energy prices or on energy independence. We do feel, however, that a $2.0 million effort is justified, provided it is expended on research in processes and systems that can potentially apply to a broad range of current industrial processes and products. Even though, for example, a long-term goal of producing hydrogen by means of thermochemical processes appears to be promising, that goal should be reached via analyses, research, and development which can be of use to the U.S. industry in the near term. The industry feels that funding for research and development in the field of fuels and chemicals should be kept at a low level until the nearer-term technology development applying to the parabolic dish, central receivers, and parabolic troughs is at a stage at which it can and will be picked up by the private sector for commercialization. Out-year budgets for sunfuels are, therefore, recommended for increases consistent with the potential impact that the fuels and chemicals systems can have on the U.S. energy situation.

B. CENTRAL RECEIVER RESEARCH AND TECHNOLOGY - CRTF OPERATIONS

The CRTF is an essential research tool in the development of the solar central receiver. The very nature of the solar source, its frequency distribution, its diffuse nature, and its variability with time, location, and weather conditions dictate that solar energy concepts be verified under real solar conditions. The ability to transfer the solar central receiver technology to the private sector at any time will depend to some extent on the degree to which the technical feasibility of the process or the performance of a component has been verified at a real solar source. In addition, private industry anticipates a need to have facilities available (much like those available for high energy physics or nuclear research) at which testing can be conducted on hardware designed and fabricated by private industry. Any given private organization could not afford or justify such a facility on the basis of the infrequent times at which its own needs must be met. Industry feels, therefore, that this need should be logically and properly met by Federal involvement. A budget of $2.0 million is recommended for FY 1984, and similar budgets are required for out-years for operation of this facility.

It is anticipated that, in the future, the capability of the CRTF will need to be improved in order to evaluate and test larger components as the size of solar thermal plants is increased under private sector development.

C. PARABOLIC DISH RESEARCH AND PROJECTS

1. COMPONENT DEVELOPMENT OF MODULES

Three industrial teams have been selected through competitive procurements to develop fully integrated modules in one of three separate engine types. Funds will be provided to these established teams to continue research and development on specific areas that have been identified as significantly reducing capital cost, increasing output, or extending useful life. Due to variations in development and funding history, the Brayton modules should receive $3.0 million, including the Solarized Automotive Gas Turbine. A total of $2.5 million is requested for the Stirling module and $0.5 million for the organic Rankine module.*

2. ADVANCED CONCENTRATOR DEVELOPMENT

Generic to all three modules is the future need to develop a significantly lower cost, high-performance concentrator similar to the accomplishments achieved by the second-generation heliostat effort. At least two detailed designs will proceed in FY 1984 for $2.5 million.

3. SYSTEM TEST AND EVALUATION

System test and evaluation of the three modules is the critical last step to reaching commercialization.. FY 1984 will provide the organic Rankine test at Osage City with $0.5 million* in operating and spare parts, $0.8 million for the second test of Stirling and/or Brayton, and $1.7 million for the third system test and evaluation of the module system not previously chosen. Outyear requirements will be an additional $3.5 million for 2 years.

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*It is assumed that the FY 1982 appropriated funds of $4.0 million and the programmed FY 1983 funds of $3.0 million will be augmented with a total $1.0 million in FY 1984 and $0.6 million in FY 1985 in order to complete the organic Rankine module development and build and operate a 100-kW system test and experiment.

4. APPLIED RESEARCH

This item covers applied research for materials, thermodynamics, and optical analysis and is estimated to require $2.0 million. The uniquely high concentration ratios and temperatures found in the parabolic dish electric technology require specialized thermal, optical, and material applied research that has been initiated, and thus far successfully performed at the Jet Propulsion Laboratory.

5. TEST FACILITY OPERATIONS

The availability of a test facility which has the capability of testing and evaluating a wide variety of dish-type concentrators, engines, receivers, and related hardware is essential in the long-term development of parabolic-dish concepts. Approximately $1.0 million is required for operation of the Parabolic Dish Test Facility to fulfill this need.

D. SALT POND RESEARCH

The solar thermal industry feels that research and development on solar pond concepts, although they can potentially lead to a technology that might have a small impact on the U.S. energy situation, should be funded at a low level of the order of $0.5 million for FY 1984 and should then continue in out-years consistent with the potential documented by the early R&D. Solar ponds are severely geographically limited in their applicability, and the intrinsic low efficiency of thermal to electric conversion makes achievement of an economically attractive technology difficult. In part, this recommendation is based upon a recognition of the fact that funding resources on the part of the federal government are now and will be limited for the near future, and that we feel that other technologies, further along toward feasibility, should be introduced into the private sector first.

E. CENTRAL RECEIVER SYSTEMS

1. SOLAR ONE AUTOMATION AND CONTROLS SOFTWARE

The Barstow Solar One plant is providing valuable operating data. An amount of $2.0 million is requested to design software for plant automation. Plant automation will result in increased plant operating time and decreased operator workload. Although all items cannot be provided within the requested funding, the items of specific interest are:

1) Automated sequences and transitions for plant startup
2) Clear and cloudy day operating scenarios
3) Supervisory controls to manage the plant resources using the operating computer system (with fewer operators)

Automation will put the plant in an operating configuration that will generate data relevant to follow-on repowering and commercial plants as the originally planned final product of the pilot plant project. Automation will lead to increased energy output of the plant and a reduction in O&M costs to ensure competitive economics of operation for commercial utility and smaller process heat applications. In these smaller scale plants, O&M costs are a major factor in plant economics and automation is essential.

Most of this work has been scheduled for FY 1983. During FY 1982 and the first and second quarters of FY 1983, unusually poor weather caused slippage in turbine roll, start-up, and manual checkout activities. Also, during the first quarter of FY 1983, equipment problems attributable to the first-of-a-kind nature of the plant, were encountered. This impacted manual checkout schedules causing delay in initiating requirements for design of automation software.

Automatic mode operation is essential to achieve maximum operating times and minimum staffing requirements to demonstrate that central receiver operating economics meet competitive expectations, important to ensure commercial acceptance. Furthermore, it is important to note that automation utilizing the digital process controller of Solar One has applications for both fossil and nuclear utility plant control systems.

2. SOLAR ONE OPERATIONS, MAINTENANCE AND ANALYSIS

This item provides $5.0 million for the continued operation of the solar plant and the test and evaluation activities:

1) An analysis of test data to compare predicted and actual plant parameters to verify design performance. Operating strategies will be identified to increase plant output and improve economics.
2) Collector (heliostat) tests and evaluations to derive beam pointing, beam quality, and reflectivity data. Heliostat cleaning requirements will be established.
3) Plant maintenance evaluations, including the analysis of equipment reliability, and the identification of preventive maintenance needed and spares required for Solar One, as well as for future plants.
4) "Lessons learned" documentation for design, construction, and operational phases.
5) Environmental assessments and heliostat field ecological impact data for future plants.
6) Data dissemination through such technical transfer activities as conferences, workshops, and written reports.

For FY 1985, operations and maintenance of the Solar One facility are expected to require $3.0 million and the completion of the Test and Evaluation activity, $2.0 million.

3. REPOWERING

The solar industry feels that the solar central receiver is close to, but not yet at, the point at which it can be turned over to the private sector. There remain three principal technical/cost barriers impeding the acceptance into the private sector. One of these is an uncertainty in the capital cost. Another is the uncertainty on the performance and cost of key components, such as the receiver at the top of the tower, the steam generator (especially reheaters), and thermal storage. The third is that, because of a lack of mass production (on heliostats in particular), the capital cost of the first few central receiver plants is likely to exceed their value in a free-market environment.

This section of the budget recommendations deals with alleviating the first of these problems. Subsequent sections will address the second issue. The third issue can be solved by means of the energy tax credit and will not be dealt with here since it is not a direct budgetary item. However, industry has already gone on record to indicate that an enhancement of the energy tax credit to 25% through December 31, 1990, is an absolutely essential element in successfully carrying out the transition of the technology to the private sector.

Under the four current preliminary design efforts that are being sponsored by DOE under a cost-sharing arrangement, significant progress is being made toward reducing the capital cost uncertainties on solar central receivers that will be needed to fill the intermediate load demand market (approximately 30 MWe and larger, and all liquid-type coolants). However, in order to reduce this uncertainty to the point at which investment bankers can raise the necessary funds for private sector ventures, more refined designs must be carried out. At the present time, the risks associated with the actual cost are too high for the private sector to undertake a specific project. Under the FY 1983 recommendations made by the industry, a total of $15 million was requested for this type of work. However, only $3.0 million was actually made available. Thus, the industry is requesting that $8.0 million be made available in FY 1984 to complete one of two final engineering designs and to initiate a second design. A sum of $4.0 million is requested for FY 1985 to complete the second design.

4. RECEIVER DEVELOPMENT

As was indicated above, one of the major barriers that impedes the ability of industry to pick up the central receiver technology is the high cost and high risk associated with the development of certain key central receiver components. Principally, these components are the receiver, the steam generator, and storage. The receiver is of particular concern since it does not have a direct counterpart in current industrial process systems. In order to reduce the perceived risk on this component to the point at which the private sector can pick it up and complete the development for commercialization, the industry recommends a base technology development effort which includes the receiver as well as the other two key components.

In FY 1983, a budget recommendation of $3.3 million was made for receiver development. Assuming that the DOE gets industry involvement on a cost-shared basis at this level during FY 1983, a budget of $4.1 million is requested for FY 1984. This money will complete fabrication of the receiver test articles and components. A budget of about $3 million will be required during FY 1985 to complete the development and test of this component.

5. STORAGE CONCEPT DEVELOPMENT

The acceptance of the central receiver as a viable energy option will be greatly enhanced by the development of a storage system that is economically viable for use in achieving gross base-load operation. Conceptual feasibility of at least one thermal energy storage system meeting these criteria has been identified and analyzed. However, technical performance and operating characteristics need to be verified before the private sector can take over the engineering development and application. The design, fabrication, test, and analysis of a test article of sufficient size to verify development potential is estimated to require a total of $2.9 million. Of the amount, $1.5 million is expected to be expended during FY 1983. During FY 1984, approximately $1.0 million is requested, with the balance of $0.4 million being needed for FY 1985.

6. STEAM GENERATOR DEVELOPMENT

Although both sodium and salt steam generators have been built in the United States, they are at very different stages of development. Both have certain unique features required for solar application that make them fall outside of the capability of solely private sector development. One of these is the use of the steam generator in the reheater mode. Currently, there are no U.S. manufacturers of steam generators for this application. Another consideration is that the nominal operating temperatures are considerably higher in the solar application than those that have been achieved in industry. These factors have led to a recommendation for a FY 1984 budget of $3.0 million, assuming that funds in the amount of about $2.5 million are allocated by DOE under a cost-sharing arrangement in FY 1983 for the early phases of this work. A budget of approximately $2.4 million for FY 1985 would be expected to be sufficient to complete this development work.

7. CONTROL SYSTEM DEVELOPMENT

Solar One is introducing a significantly advanced control system into the utility industry. In addition to the software development outlined in Item 1, $2.0M is requested to implement the fully automated advanced control system. When fully implemented, this advanced system, using a high level of graphics display and automation, will reduce staffing and increase the plant's net electrical output. It will provide lowest cost operations for developers of repowering systems and for the next generation of 30-MW to 100-MW solar central receiver plants as well as for Solar One.

F. DISTRIBUTED RECEIVER SYSTEMS - OPERATIONS AND EVALUATIONS

The industry recommends data acquisition and continued operation of existing systems at a $1.5-million level. It is in the best interest of the line focus industry and the government that existing federally funded systems be operated long enough to obtain useful data on system performance, degradation with time, reliability, maintainability, etc. Funds are required in FY 1984 to insure that systems which have recently come on line or have recently been upgraded will be operated for a sufficient period to permit useful data to be obtained so as to justify the investment of federal funds in the project. This activity is expected to continue through FY 1985 at this funding level.

G. PLANNING AND PROGRAM SUPPORT

Approximately $2.0 million is recommended by the industry for allocation in the area of planning and coordination of solar thermal activities. These activities should be directed toward all technologies, with emphasis on longer term activities. The industry opposes activities dealing with cost goals, since such activities tend to have a negative effect on private-sector marketing activities. This activity is expected to continue in out-years at approximately this level.

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APPENDIX A
(PAGES 38-48)

SOLAR ENERGY RESEARCH AND DEVELOPMENT:

FEDERAL AND PRIVATE SECTOR ROLES

REPORT OF THE ENERGY RESEARCH ADVISORY BOARD

Prepared by the

SOLAR R&D PANEL

September 1982

V. SOLAR THERMAL

A. Critical R&D Issues

1. Introduction

Solar thermal energy systems convert the sun's radiant energy to heat energy. The heat may then be used directly for industrial applications or to generate electricity. A unique feature of the solar resource is the ability to use radiant energy to produce high temperatures. Temperatures up to 1370°C can be achieved. To date, a 20% net conversion efficiency of sunlight in to electricity out has been achieved at the Solar One Central Receiver Plant. A net efficiency of 26% has been attained with a Parabolic Dish/Stirling Engine system.

Solar thermal covers five different technologies. These exhibit varying degrees of technical maturity and acceptance in the marketplace. With the exception of solar ponds, the solar thermal technologies concentrate solar energy to various degrees, sufficient to achieve higher efficiencies for the production of industrial process heat, electricity, and fuels.

2. Parabolic Troughs

Parabolic troughs are the solar thermal technology with which there has been the most experience. A number of systems are in operation. More than three-quarters of a million square feet of collectors have been installed as a result of field test experiments, research and development projects, and commercial sales. In successive projects, parabolic trough systems have demonstrated increasingly higher efficiencies, higher reliability and lower costs.

3. Central Receivers

Solar thermal central receiver technology is a near-commercial solar energy option for electric power production for utility systems. If the current momentum in this technology can be maintained, commercial application of central receivers can begin during the next few years. However, it is at this point—the demonstration stage—that some specific government involvement is most critical to ensure a successful transfer of technology to the risk-adverse utility industry.

The best evidence of the status of development of solar central receiver technology is seen at the 10 MW "Solar One" pilot plant near Barstow, California. Operation began on April 12, 1982, with initial power production to the Southern California Edison electric grid. After a three to four month start-up period, a five-year test program will begin this year. The first two years of operation will include experimental testing of the major subsystems and evaluation of operation, maintenance requirements and costs. This period will be followed by power production tests to obtain longer term operation, maintenance, reliability, and cost data.

In addition to Solar One, five other similar, but smaller (1/2 to 2MW), government sponsored central receiver pilot plants are starting up in Western Europe (Spain, France and Italy) and Japan. These pilot projects serve as laboratory facilities to provide information and firsthand experience with the operation and maintenance of this new technology. Various industrial concerns are currently considering even larger installations. Utilities and equipment manufacturers are watching and monitoring progress to more accurately assess performance and cost for the next installation, perhaps in the 30-100 MW range.

Extensive component testing has also occurred in the U.S. in recent years. Four different receiver concepts using different heat transfer fluids--air, water, salt, and sodium (the latter at private expense)--have been tested and show encouraging results. Also, four complete second generation heliostat systems have been tested.

Results from these prototype tests and studies have demonstrated that commercial scale production of sun-tracking heliostats is feasible and can be economically attractive in large quantity production. There appears to be no insurmountable technical barrier to the successful development of central receiver systems.

4. Parabolic Dishes

Parabolic dish concentrators provide two-axis tracking of the sun for high collector efficiency coupled with highly efficient heat engines. Each concentrator/engine unit or module can independently produce thermal and electrical energy. This technology represents a particularly promising technology for a diverse market ranging from small isolated loads to multi-megawatt grid-connected systems. Recent tests using Stirling and organic Rankine engines established technical feasibility and sunlight conversion efficiencies in excess of 26%. The modularity of these 20 to 25 KWe units, as well as a short lead time for construction, provide favorable flexibility in load planning and financing of new electric generating capacity.

The technology is new. Considerable generic research remains to be done, particularly in the areas of reflective and ceramic materials, non-gaseous fueled hybrid receivers to increase capacity factors, system level controls, and alternative concentrator design. Small, multi-unit prototype projects will be required to develop proof that parabolic dish systems for electricity production can interact on an autonomous basis. The cost of such a program is relatively small and cost sharing should be encouraged.

5. Hemispherical Bowls

A 65-foot hemispherical bowl is operating in Crosbyton, Texas, and there is interest in expanding the concept to one or ten 200-meter hemispherical bowls to operate in conjunction with a new fossil fuel power plant. Cost for the power plant and one hemispherical bowl is estimated to be $10.6 million. The cost for the power plant and ten bowls is between $28 and $31 million. The remaining critical R&D issue primarily lies with low annual collection efficiency, high thermal losses, and the scaling up of the prototype design to 200 meters. However, the Panel is concerned about the comparatively low average annual collection efficiency of this technology, the thermal losses associated with the long piping of the collected thermal energy and the appropriateness of DOE funding all or part of the cost for the fossil fuel portion of the proposed demonstration plant.

6. Solar Ponds

Solar pond technology for both heat and electricity production is still in the developmental stage. It holds some promise for commercial use in those regions of the nation where huge amounts of saline water and flat, open terrain are readily available. This technology is currently being demonstrated in a two-acre pond at Ein-Bokek in Israel, generating 150 KW of electricity. The construction of a 10-acre, 5 MW pond at the Dead Sea in Israel is 60% complete, and the pond is scheduled to be in operation in 1983.

Development of the solar pond technology in the United States is confined to laboratory tests and feasibility studies. With support from the Department of Energy, Southern California Edison and the California Energy Commission conducted a 5 MW Salton Sea feasibility study. The Jet Propulsion Laboratory and the Army Corps of Engineers have also conducted tests on pond characteristics. A number of major site-related pond technology questions, such as maintenance of water clarity, local brine production, permeability of pond bottoms, questions relating to wind suppresion, and salt gradient stability, maintenance of the salinity and thermal stratification, and environmental protection remain to be resolved. On the conversion-plant technological front, brine removal and return, brine nozzles, heat exchanger and efficiency improvements remain to be resolved. On a site specific basis, solar ponds may offer a productive use of brines generated from desalinization plants.

To supplement Israeli experience, to address site specific characteristics and to evaluate different environmental and operating requirements, the Panel has considered the importance and feasibility of the United States developing its own technical base for this application. The progress of solar salt pond technology, from a few megawatt proof-of-concept pilot plant to full fledged commercial plants of tens-to-hundreds of megawatts would require successful experimental plant tests in perhaps two locations. At the same time, site specific pond-related studies and tests at various resource locations would have to be done to be followed by commercial installations based on experience and data.

7. Fuels Production Using Solar Thermal Technologies

Finally, there is the technical possibility of using solar thermal processes to derive fuels and chemicals. Solar thermal energy systems can be used to produce, efficiently and economically, a variety of fuels and chemicals—

including hydrogen. Solar is capable of driving high temperature (greater than 2000°F), thermo-chemical reactions, high flux (greater than 1MWe/M), non equilibrium reactions and direct photon driven processes. Solar thermal systems can provide a combination of temperature and flux not achievable through conventional process design, which can significantly enhance efficiency and result in higher value products.

8. Technology Base R&D

A number of critical R&D areas have promise for providing the technology base necessary for the next generation of solar thermal technologies including improved central receiver, dish and trough systems, with considerably improved performance and reduced energy costs. These include:

- The development of new materials with good optical qualities and long life
- The development of lightweight, low cost concentrating structures
- The development of high temperature materials
- Research into the use of thermal processes for fuels production which should be coordinated with similar activities in the biomass energy area.

Environmental issues related to solar collectors include land use (6-8 acres per megawatt for central receivers and parabolic dishes), esthetics in some cases, and, in a few cases, bird and insect mortality.

B. State of the Industry

There is a diverse cross section of American industry in solar thermal technologies, ranging from the small high technology firms to the large aerospace and petroleum companies. Fifty-seven companies represent the nucleus of the industry. The majority of larger firms are engaged in central receiver technology. The larger companies can be characterized generally as risk averse, while the smaller companies have limited economic strength.

Most of these companies are seeking sales of their first generation hardware by capitalizing on the Federal and State energy tax credits to help obtain financing; many depend upon venture capital. Two recent announcements by the parabolic trough industry of purchase power agreements with Southern California Edison (SCE) provide an indication that these systems may be on the verge of becoming commercial. However, recent market uncertainties and general economic conditions may hinder commercialization of this technology at this time. The central receiver industry is bidding on both the design phase of a DOE Program Opportunity Notice and a Notice of Program Interest from SCE that will provide the detailed design effort and market pull for near-term implementation.

In summary, the parabolic dish, hemispherical bowl and salt ponds are not yet ready for first generation commercial sales.

C. Transfer of Federal R&D

The DOE Solar Thermal Program has had close and continuing coordination with the developing industries in each of the technology areas. Approximately 75% of its R&D funds were spent through industry and, thereby, ensured an early development of personnel, expertise, and hardware transfer. DOE test facilities are used by industry for trough testing. The program has held annual technical review meetings and many topical symposia and workshops.

A number of factors inhibit rapid industrial investment in solar thermal technologies which otherwise are rapidly nearing commercial status. These include: a difficult investment climate and high interest rates, the added risk of a new technology without a long record of performance, and a complicated regulatory framework. To these inhibitors is added the uncertainty about the continuation of the Federal energy tax credits. These points are discussed in detail in Chapter X as common problems for many emerging solar technologies.

D. Recommended Federal and Private Sector Roles and Objectives

1. Parabolic Troughs

The parabolic trough technology is commercially available and requires only a low order of continued DOE support in materials research (including environmental testing) and operational testing of key demonstration projects to complete the technology transfer process.

There appears to be a minimal role for DOE after the completion of the FY 82 funded Modular Industrial Solar Retrofit (MISR) design and testing effort. Thereafter, the R&D critical issues are directly associated with the generic need for low cost, long life reflective surfaces, and receiver materials of high absorbtance and long life. Operation of a select number of DOE sponsored demonstration projects should be continued for gathering data to resolve these R&D issues and transfer of the technology to industry.

2. Central Receivers

The paramount requirement of the Federal solar thermal central receiver program over the coming years is to ensure that the Solar One experiment is carried through to a logical and thoroughly understood conclusion. Success in this activity will require completion of the plant's automatic control system, extensive operation coupled with thorough evaluation of the plant's performance and operating requirements, and dissemination of test data and operating experience to all interested parties. In defining the remainder of the Solar One program, the overall aim must be to maximize the benefit to the country of the extensive public expenditure to date, rather than to seek an expedient path for completing the experiment at minimum incremental cost. The outcome of the Solar One experience will have far greater bearing on any subsequent initiatives in solar thermal central receiver systems than any other single activity.

In addition, the DOE should cost share with industry on programs that will prove advanced receiver and thermal storage concepts. One such test, which is being organized under EPRI auspices, is the Molten Salt Electric Experiment at the Central Receiver Test Facility (CRTF) in Albuquerque, New Mexico.

The private sector is actively pursuing various avenues to move the technology out of the demonstration phase. For example, the recently issued Solar Program Opportunity Announcement by the Southern California Edison Company for the construction of a pre-commercial plant* by 1988 is seen as a critical first step to commercialization. However, these efforts by the private sector assume continued Federal support, including operation of Solar One, system and component develoment and tests at CRTF, cost-shared support for repowering, and the extension of the business energy tax credit beyond 1985.

3. Parabolic dish

The DOE should redirect its emphasis to the parabolic dish program for further technology development because of its potentially higher efficiencies and lower costs. Future component research should concentrate on areas that will either significantly improve known efficiencies, extend the useful life, or reduce the capital and operating costs of the modules. Small multi-module experiments should be programmed on a cost-sharing basis. The ability of the parabolic dish program to pursue three heat engine options needs to be evaluated in relation to the long-term market requirements and the availability of complementary Federal funds in the automotive engine R&D programs.

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*A pre-commercial plant is defined as a custom-made, first-of-a-kind facility whose components are not yet in commercial production.

4. Hemispherical Bowl

Hemispherical bowl technology, specifically the Crosbyton Project, has had $4.0 million in FY 82 appropriated from the Solar Reserve Fund. Continued funding of this project in FY 83 and beyond would be undesirable, especially considering the Panel's overall recommendation against large scale demonstration projects. The inherently low average annual collection efficiencies, high thermal piping losses and a rather isolated market pull, discourage further R&D support for hemispherical bowl technology.

5. Solar Ponds

The Panel is not convinced of the prospects for solar pond technology. In view of the foreign leadership in solar pond technology the Panel recommends the maintenance of only a small technical staff to monitor progress in this field. Should DOE find it appropriate, specific research and development may be warranted in the future.

6. Demonstration Projects

No new large scale demonstration projects can be advocated under the present budgetary constraints. The only role for the DOE would be to provide data acquisition equipment and data reduction costs in order to improve technology transfer throughout the industry.

7. Technology Base R&D

The DOE basic and applied research program for solar thermal must achieve a sharper focus based on anticipated availability of first generation technology. Priority should be given to optical, thermal and structural materials; the sciences of thermodynamics, heat and mass transfer; and fuels production.

Many of these research areas will produce results useful to all the solar thermal technologies.

The Federal role should be to coordinate generic research needs in all the solar thermal areas. These include reflective and ceramic materials, operation of vital systems level experiments for technology transfer, and participation in the second generation of component development.

8. Summary of Private Sector Roles

The parabolic trough industry has indicated the existence of entrepreneurial interests in marketing its first generation systems for both industrial process heat and electrical applications, provided private financing can be obtained. The private sector will provide the system level engineering required for large scale sales. The central receiver industry is similarly pursuing first generation sales but there is a far greater need to rely on development of future components, volume sale of heliostats, and continuation of the energy tax credit. The parabolic dish industry will be required to perform R&D and engage in small, system level experiments on a cost-sharing basis before first generation technology will be ready for the marketplace. The hemispherical bowl and salt pond technologies do not appear to have an industrial participant that would undertake, on a cost-sharing basis, the technical and economic risks of the proposed demonstration projects.

Senator **Warner**. Well, we are going to have to put the questions in for the record. This is a subject, as all of these subjects, that interests me a great deal.

What do you tell the people who come up to any of us in the Congress excited about the prospects of solar energy with respect to how soon we might expect a greater use of solar energy in the homes?

Mr. **Seielstad**. Well, Senator, I think that in the home there are two elements which are to be realized, one of which can be immediately realized.

I am also responsible for solar heating research, and we have a data base right now which indicates cost effectiveness as well as technical efficacy of passive solar domestic hot water and passive space heating, and we recommend these programs to our customers as being in their own economic self-interest, and strange as it may seem, it is in our company's economic self-interest because by enabling our customers to reduce their dependency on purchased energy, we can postpone our investment in new power plants which are not to the best interests of our ratepayers currently, so we honestly advocate conservation of energy. As a second phase to that conservation advocacy, we advocate that our customers adopt solar heating.

Now the longer range, there is tremendous potential in the photovoltaic sector where our customers could potentially implement photovoltaics to pick up part of the electrical load right on their own roofs, and the utilities just announced a few weeks ago a 16½-megawatt centralized photovoltaic facility in conjunction with Atlantic Richfield Solar Industries—by far the world's largest photovoltaic installation.

That would provide energy for thousands of homes through the conventional distribution system in the grid.

Senator **Warner**. I see.

Mr. **Seielstad**. Beyond that comes the solar receiver technology which is a more adaptable technology between peaking and intermediate and what we call base load. The energy is storeable so it can operate in a fashion similar to that of a coal plant or nuclear plant, so the potential is quite enormous.

The realization of it is proceeding more slowly than what I would hope, but the Congress can act to expedite the process.

Mr. **Casazza**. Might I add just a few comments on that? My name is John Casazza. I am representing the Institute of Electrical & Electronics Engineers.

One of the great problems of applying new technology, particularly solar, is the problem of integrating it into the existing buildings, homes, office buildings such as this. It is not easy. If you design something from scratch it is quite easy to integrate solar applications, and probably in many areas they will be economically desirable, so part of the problem is in applying solar energies to recognize that we have a very considerable investment in buildings, homes, factories, and so on, where it is going to take a lot of time to integrate solar into them.

We have to look for solar technologies that have the advantage of ease of integration because we do have to keep these buildings functioning in our society. We cannot abandon all of our structures because we want to apply a new type of energy supply, so that is one of the problems, and along with it the cost in a great many cases, as I said in my testimony.

The cost is too high at the present time and needs research funds to get it down to where it is commercially competitive.

Senator WARNER. Thank you, gentlemen, very much, for assisting this committee and other Members of the Senate.

The hearing is adjourned.

[Whereupon, at 12:30 p.m., the hearing was adjourned.]

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